

1 Assignments

Your grade in this course will be based on weekly homeworks and two exams. The homeworks are worth 80% of your final grade and each exam is worth 10%.

2 Class Schedule

2.1 Week 1: Complex Numbers and Framing

- Lecture 1: Introduction
- Lecture 2: Algebra of Complex Numbers
- Lecture 3: Geometry of Complex Numbers and Phase

2.2 Week 2: Complex Vector Spaces (Review)

- Lecture 4: C^n as a Vector Space
- Lecture 5: Bases, Inner Products, and Norms
- Lecture 6: Eigenvalues, Hermitian and Unitary Matrices

2.3 Week 3: Tensor Products and the Classical–Quantum Transition

- Lecture 7: Tensor Products and System Composition
- Lecture 8: Deterministic and Probabilistic Systems
- Lecture 9: Quantum Systems and First Qiskit Circuits

2.4 Week 4: Basic Quantum Theory

- Lecture 10: Quantum States and Dirac Notation
- Lecture 11: Observables and Measurement
- Lecture 12: Quantum Dynamics and Assembling Systems

2.5 Week 5: From Quantum Mechanics to Quantum Computation

- Lecture 13: The Quantum Computation Model (Qubits, Gates, and Circuits)
- Lecture 14: Quantum Circuits and Information Flow
- Lecture 15: Superposition, Interference, and Algorithmic Thinking

2.6 Week 6: Quantum Algorithms I

- Lecture 16: Deutsch's Algorithm
- Lecture 17: The Deutsch–Jozsa Algorithm
- Lecture 18: Circuit Implementations of Deutsch–Jozsa

2.7 Week 7: Quantum Algorithms II

- Lecture 19: Simon's Periodicity Algorithm
- Lecture 20: Grover's Search Algorithm
- Lecture 21: Grover's Algorithm: Scaling and Limits

2.8 Week 8: Shor's Algorithm and the Quantum Fourier Transform

- Lecture 22: Modular Arithmetic and Period Finding
- Lecture 23: The Quantum Fourier Transform
- Lecture 24: Shor's Factoring Algorithm

2.9 Week 9: Quantum Programming Languages

- Lecture 25: Programming in a Quantum World
- Lecture 26: Quantum Assembly and High-Level Programming
- Lecture 27: Quantum Computation Before Quantum Computers

2.10 Week 10: Theoretical Computer Science Foundations

- Lecture 28: Deterministic and Nondeterministic Computation
- Lecture 29: Probabilistic Computation
- Lecture 30: Quantum Computation and Complexity Classes

2.11 Week 11: Quantum Cryptography

- Lecture 31: Classical Cryptography and Threat Models
- Lecture 32: Quantum Key Exchange: BB84 and B92
- Lecture 33: Entanglement, EPR Protocols, and Teleportation

2.12 Week 12: Information Theory

- Lecture 34: Classical Information and Shannon Entropy
- Lecture 35: Quantum Information and von Neumann Entropy
- Lecture 36: Information, Decoherence, and Limits of Quantum Systems

2.13 Week 13: Quantum Optimisation

- Lecture 37: Formulating Optimisation Problems for Quantum Computation
- Lecture 38: Ising Models, Max-Cut, and QUBO Formulations
- Lecture 39: Quantum Optimisation Algorithms and Variational Circuits

2.14 Week 14: Quantum Machine Learning

- Lecture 40: Mathematical Foundations of Machine Learning (Review)
- Lecture 41: Quantum Support Vector Machines and Kernel Methods
- Lecture 42: Quantum Neural Networks and Variational Learning

2.15 Week 15: Information, Error, and Physical Reality

- Lecture 43: Classical and Quantum Data Compression
- Lecture 44: Quantum Error-Correcting Codes and Fault Tolerance
- Lecture 45: Noise Models, Decoherence, and Error Mitigation

2.16 Week 16: Hardware, Limits, and Synthesis

- Lecture 46: Quantum Hardware Platforms and Architectural Constraints
- Lecture 47: When Quantum Helps, When It Fails, and When It Is Irrelevant
- Lecture 48: Conclusion