NATIONAL UNIVERSITY OF SAN MARCOS

FACULTY OF MATHEMATICAL SCIENCES

SYLLABUS

1. GENERAL INFORMATION

1.1 Course name	:	Introduction to Quantum Computing
1.2 Code	:	QC381
1.3 Academic Program	:	Scientific Computing
1.4 Credits	:	4
1.5 Prerrequisites	:	• QC251. Quantum Mechanics. (8^{th} Sem) • MA381. Algebraic Structures. (9^{th} Sem)
1.6 Type of Course	:	Elective
1.7 Area of Studies	:	Estudios Generales
1.8 Number of Weeks	:	16
1.9 Hours per week	:	2 HT; 4 HP;
1.10 Cycle	:	I
1.11 Learning modality	:	Face to face
1.12 Academic Period	:	2026-I
1.13 Semester Start Date	:	
1.14 Semester End Date	:	

2. PROFESSORS

Meetings after coordination with the professor

3. INTRODUCTION TO THE COURSE

This course introduces the fundamental principles of quantum computing, including qubits, superposition, entanglement, quantum algorithms, and hardware. Students will contrast classical and quantum models, exploring applications in cryptography, optimization, physical simulation, and quantum machine learning, using frameworks like Qiskit or Cirq. Includes a practical module on hardware architectures (superconductors, ion traps) and their impact on algorithm design.

4. GOALS

- Understand the postulates of quantum mechanics applied to computing.
- Implement basic quantum circuits and optimization algorithms.
- Analyze the ethical, technical, and commercial impact of quantum computing.
- Evaluate hardware limitations in real-world applications.

5. COMPETENCES

ABET-1) An ability to identify, formulate, and solve broadly defined technical or scientific problems by applying knowledge of mathematics and science and/or technical topics to areas relevant to the discipline. (Usage)

ABET-3) An ability to develop and conduct experiments or test hypotheses, analyze and interpret data, and use scientific judgment to draw conclusions. (Usage)

6. TOPICS

Unit 1: Foundational concepts (10 hours)	
Competences Expected: ABET-1,ABET-3	
Topics	**Learning Outcomes**
• Qubits and Bloch sphere representation. • Postulates of quantum mechanics. • Quantum gates (Hadamard, CNOT, Toffoli).	• Mathematically model a qubit [Usar]. • Simulate basic operations in Qiskit [Evaluar].
Readings : [**NielsenChuang**], [**QiskitTextbook**]	

Unit 2: Quantum Architectures (10 hours)

Competences Expected: ABET-1,ABET-3

Topics	Learning Outcomes
• Principles: – The wave-particle duality principle – The uncertainty principle in the double-slit experiment – What is a Qubit? Superposition, interference, and measurement. Photons as qubits – Systems of two qubits, Entanglement, Bell states, The No-Signaling theorem • Axioms of QM: superposition principle, measurement axiom, unitary evolution • Single qubit gates for the circuit model of quantum computation: X, Z, H • Two qubit gates and tensor products, working with matrices • The No-Cloning Theorem. The Quantum Teleportation protocol • Algorithms: – Simple quantum algorithms: Bernstein-Vazirani, Simon's algorithm – Implementing Deutsch-Josza with Mach-Zehnder Interferometers – Quantum factoring (Shor's Algorithm) – Quantum search (Grover's Algorithm) • Implementation aspects: – The physical implementation of qubits – Classical control of a Quantum Processing Unit (QPU) – Error mitigation and control, NISQ and beyond – Measurement approaches • Emerging Applications: – Post-quantum encryption – The Quantum Internet – Adiabatic quantum computation (AQC) and quantum annealing	• Discuss how a quantum object produced as a particle propagates like a wave and is detected as a particle with a probability distribution corresponding to the wave [Debate] • Discuss the quantum-level nature that is inherently probabilistic [Debate] • Express your view on entanglement that can be used to create non-classical correlations, but there is no way to use quantum entanglement to send messages faster than the speed of light [Evaluate] • Describe quantum parallelism and the role of constructive vs destructive interference in quantum algorithms given the probabilistic nature of measurement(s) [Describe] • Analyze a code snippet providing the role of quantum Fourier transform (QFT) in Shor's algorithm [Analyze] • Write a program to implement Shor's algorithm in a simulator, highlighting the classical components and aspects of Shor's algorithm [Write] • Enumerate the specifics of each qubit modality (e.g., trapped ion, superconducting, silicon spin, photonic, quantum dot, neutral atom, topological, color center, electron-on-helium) [Enumerate] • Contrast AQC with the gate model of quantum computation and the problems each is better suited to solve [Contrast]

Readings : [**QuantumHardwareBook**], [**IBMQuantumRoadmap2023**]

Unit 3: Algorithmic Strategies (12 hours)	
Competences Expected: ABET-1,ABET-3	
Topics	**Learning Outcomes**
• Quantum computing • Deutsch-Jozsa algorithm. • Grover's search (applied to combinatorial optimization). • Shor's factorization and its impact on RSA.	• Implement Grover for SAT problems [Usar].
Readings : [**PreskillNotes**], [**QiskitTextbook**]	

Unit 4: Formal Languages and Automata (10 hours)	
Competences Expected: ABET-1,ABET-3	
Topics	**Learning Outcomes**
• Quantum computation: – Postulates of quantum mechanics: ∗ State space ∗ State evolution ∗ State composition ∗ State measurement – Column vector representations of qubits – Matrix representations of quantum operations – Simple quantum gates (e.g., XNOT, CNOT) • Quantum Approximate Optimization Algorithm (QAOA). • Logistics/finance applications (Portfolio Optimization).	• For a quantum system give examples that explain the following postulates: – State Space - system state represented as a unit vector in Hilbert space – State Evolution - the use of unitary operators to evolve system state – State Composition - the use of tensor product to compose systems states – State Measurement - the probabilistic output of measuring a system state. [Familiarizarse]. • Design a QAOA for routing problems [Evaluar].
Readings : [**QMLBook**], [**Bravyi2022**]	

Unit 5: Ethics and Post-Quantum Security (6 hours)	
Competences Expected: ABET-1,ABET-3	
Topics	**Learning Outcomes**
• Post-quantum cryptography (NIST PQC Standardization). • Quantum supremacy: technical/ethical debate. • Patents and quantum geopolitics.	• Propose post-quantum migration strategies [Familiarizarse].
Readings : [**QuantumSupremacyPaper**]	

7. WORKPLAN

7.1 Methodology

Individual and team participation is encouraged to present their ideas, motivating them with additional points in the different stages of the course evaluation.

7.2 Theory Sessions

The theory sessions are held in master classes with activities including active learning and roleplay to allow students to internalize the concepts.

7.3 Practical Sessions

The practical sessions are held in class where a series of exercises and/or practical concepts are developed through problem solving, problem solving, specific exercises and/or in application contexts.

8. EVALUATION SYSTEM

********* EVALUATION MISSING ********

9. BASIC BIBLIOGRAPHY