NATIONAL CENTRE FOR QUANTUM COMPUTING (NCQC)

Narowal Lab · UET Narowal Campus, Pakistan · Instructor: Syed Abbas Zilqurnain Naqvi

CRASH COURSE 01 · ONE-MONTH INTENSIVE

Mathematical Foundations of Quantum Computing

One-Month Crash Course · 2 Lectures Per Week · Module Schedule

8 Modules · 4 Weeks · 8 Lectures · 20 Contact Hours · Saturday & Tuesday · 9:00–11:30 AM

SESSION SCHEDULE

Theory / Concepts	Mathematical Content	Lab / Practical (Qiskit)	Review / Assessment

Week	Lec #	Day & Date	Time	Module	Session Title	Topics Covered	Duration	Type
WEEK 1 — Linear Algebra & Qubit Fundamentals								
Wk 1	L-01	SaturdayWeek 1	9:00 – 11:30 AM	M01	**Linear Algebra for Quantum Systems**	• Fields, vector space axioms & subspaces • Linear combinations, span & independence • Basis & dimension · Change of basis • Bra-ket (Dirac) notation: |ψ⟩ and ⟨ψ| • Complex vector spaces · |0⟩ and |1⟩ basis	2.5 hrs	**Maths**
Wk 1	L-02	TuesdayWeek 1	9:00 – 11:30 AM	M02 + M03	**Qubits & Inner Product Spaces**	• Qubit: α|0⟩ + β|1⟩ · Normalisation $\|\alpha\|^2+\|\beta\|^2=1$ • Bloch sphere · polar angles θ, ϕ • Inner product axioms: conjugate symmetry & linearity • Orthogonality: ⟨0|1⟩=0 · Orthonormal bases • Induced norm ‖ψ‖ · Hilbert space & Gram-Schmidt	2.5 hrs	**Maths**
WEEK 2 — Linear Operators & Spectral Theory								
Wk 2	L-03	SaturdayWeek 2	9:00 – 11:30 AM	M04-A	**Hermitian & Unitary Operators**	• Linear maps & matrix representation • Adjoint (Hermitian conjugate) $A^\dagger$ • Hermitian operators: $A^\dagger=A$ · physical observables • Unitary operators: $UU^\dagger=I$ · reversibility of evolution • Pauli matrices X, Y, Z · commutator [A,B]	2.5 hrs	**Maths**

Week	Lec #	Day & Date	Time	Module	Session Title	Topics Covered	Duration	Type
Wk 2	L-04	TuesdayWeek 2	9:00 – 11:30 AM	M04-B	**Eigenvalues, Spectral Decomposition & Projectors**	• Eigenvalue equation A|v⟩ = λ|v⟩ • Diagonalisation theorem • Spectral decomposition: A = Σ λᵢ|vᵢ⟩⟨vᵢ| • Projectors: P²=P, P†=P • Operator functions & matrix exponential e^(iθA) • Quiz 1: Modules 01–04	2.5 hrs	Maths
WEEK 3 — Tensor Products, Entanglement & Quantum Postulates								
Wk 3	L-05	SaturdayWeek 3	9:00 – 11:30 AM	M05	**Tensor Products & Quantum Entanglement**	• Tensor product of vector spaces V⊗W • Computational basis: |00⟩, |01⟩, |10⟩, |11⟩ • Operators on tensor spaces: A⊗B • Separable vs entangled states • Bell states: (|00⟩±|11⟩)/√2 · non-local correlations	2.5 hrs	Theory
Wk 3	L-06	TuesdayWeek 3	9:00 – 11:30 AM	M06	**Four Postulates of Quantum Theory**	• Postulate I: state space as Hilbert space $\mathcal{H}$ • Postulate II: Schrödinger equation iℏd|ψ⟩/dt=H|ψ⟩ • Postulate III: projective measurement & Born rule P(m)=⟨ψ|$M_m^\dagger M_m$|ψ⟩ • Postulate IV: composite systems via tensor product • Observables · expectation values · uncertainty principle • Quiz 2: Modules 05–06	2.5 hrs	Theory
WEEK 4 — Quantum Circuits, Teleportation & Assessment								
Wk 4	L-07	SaturdayWeek 4	9:00 – 11:30 AM	M07 + M08	**Quantum Circuits & Teleportation Protocol**	• Circuit model: wires = qubits, boxes = gates • Single-qubit gates: X, Y, Z, H, S, T · gate universality • CNOT, SWAP, Toffoli (CCX) gates • Teleportation: Alice's CNOT+H+measure • Bob's feedforward correction · no-cloning theorem	2.5 hrs	Theory
Wk 4	L-08	TuesdayWeek 4	9:00 – 11:30 AM	Review	**Comprehensive Review & Final Assessment**	• Consolidation: all 8 modules • Worked problems: operators, circuits, postulates • Quiz 3: Modules 07–08 • Final written assessment (45 min) • Feedback, Q&A & certificate distribution	2.5 hrs	Review

COURSE NOTES & LOGISTICS

Course Duration: 4 Weeks · 8 Lectures total · 2 lectures per week (Saturday & Tuesday)

Session Timing: 9:00 AM – 11:30 AM · 2.5 hours per lecture · Total: 20 contact hours

Format: In-person at NCQC Narowal Lab, UET Narowal Campus. All study materials provided.

Assessment: 3 in-lecture quizzes (40%) + Final written assessment (60%)

Prerequisites: High-school mathematics only. No physics or quantum prior knowledge required.

Class Size: Maximum 25 participants for optimal interaction.