	MAHATMA GANDHI UNIVERSITY **Kottayam, Kerala** **Undergraduate Programmes (HONOURS)** **2025 Admission Onwards**

SYLLABUS			
SIGNATURE COURSE			
Name of the College	Bishop Abraham Memorial College, Thuruthicaud		
Faculty/ Discipline	Physics		
Programme	BSc (Hons) Physics		
Course Coordinator	Ens Mathews		
Contributors			
Course Name	Fundamentals for Quantum Computing		
Type of Course	DSE		
Specialization title	Quantum Computing		
Course Code	MG3DSEPHYA05		
Course Level	200		
Course Summary	This course introduces the fundamental concepts required for quantum computing, combining essential mathematics and basic quantum mechanics. It covers linear algebra, complex vector spaces, and probability, followed by quantum principles such as state vectors, operators, measurement, and Dirac notation. Students learn about qubits, superposition, and basic multi-qubit systems, with an introduction to entanglement. The course also outlines unitary evolution, simple quantum gates, and physical realizations of qubits. Emphasis is placed on conceptual understanding and mathematical readiness, providing a strong foundation for advanced topics in quantum circuits, algorithms, and quantum information in subsequent courses.		
Semester	3	**Credits**	4
Course Details			
Pre-requisites, if any	Students should have a basic understanding of higher secondary (Class XII) Mathematics and Physics.		

Course Details:

Learning Approach	**Lecture**	**Practical/Lab-P**	**Total Hours**
Credits	3	1	75

Course Outcomes (CO)

Number of COs		**5**	
CO No.	**Expected Course Outcome**	**Learning Domains ***	**PO No**
1	Apply fundamental mathematical tools such as complex numbers, vector spaces, matrices, and eigenvalue problems to represent and analyze quantum systems.	A	PO1, PO2, PO3, PO4, PO5, PO10
2	Explain the basic postulates of quantum mechanics and use Dirac notation to describe quantum states, operators, and measurement processes.	U	PO1, PO2, PO3, PO4, PO5, PO10
3	Describe qubits, superposition, and multi-qubit systems, and interpret quantum states using representations such as the Bloch sphere.	U	PO1, PO2, PO3, PO4, PO5, PO10

Number of COs		5	
CO No.	Expected Course Outcome	Learning Domains *	PO No
4	Understand basic quantum gates, and measurement in quantum state evolution, and relate these concepts to physical implementations of quantum computing.	U	PO1, PO2, PO3, PO4, PO10
5	Perform basic quantum simulations.	A	PO1, PO2, PO3, PO4, PO10

**Remember (K), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*

CO-PO Articulation Matrix

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	3	3	3	2	1	-	-	-	-	1
CO 2	3	3	3	2	1	-	-	-	-	1
CO 3	3	3	3	2	1	-	-	-	-	1
CO 4	3	3	3	1	-	-	-	-	-	1
CO 5	3	3	3	2	-	-	-	-	-	1

‘0’ is No Correlation, ‘1’ is Slight Correlation (Low level), ‘2’ is Moderate Correlation (Medium level) and ‘3’ is Substantial Correlation (High level).

Course Content

Content for Classroom transaction (Units)

Module	Units	Course Description	Hrs	CO No.
1	Mathematical Foundations for Quantum Computing			
	1.1	Complex Numbers and Vectors: Complex numbers and Argand plane - Euler representation - Vectors and vector spaces - Linear combinations and linear independence.	5	["1"]
	1.2	Vector Spaces and Matrices: Basis and dimension - Inner product spaces - Norm, orthogonality, orthonormal basis - Matrix algebra and types (Hermitian, Unitary).	5	["1"]
	1.3	Eigenvalue Problems and Probability: Eigenvalues and eigenvectors - Diagonalization (basic idea) - Tensor (Kronecker) product - Classical vs quantum probability - Probability amplitudes.	5	["1"]
2	Fundamentals of Quantum Mechanics for Computing			
	2.1	Introduction to Quantum Theory: Failure of classical physics (brief) - Wave-particle duality - Wavefunction and physical interpretation.	4	["2"]
	2.2	Formalism of Quantum Mechanics: Postulates of quantum mechanics - Dirac (bra-ket) notation - Operators and observables - Expectation values.	4	["2"]
	2.3	Measurement and Dynamics: Measurement postulate - Commutation relations - Time-independent Schrödinger equation (conceptual) - Stationary states (basic idea).	4	["2"]

Module	Units	Course Description	Hrs	CO No.
3	Quantum States and Qubits			
	3.1	Qubits and Superposition: Classical bit vs qubit - Basis states $\lvert 0\rangle$, $\lvert 1\rangle$ - Superposition principle - Probability amplitudes.	4	["3"]
	3.2	Representation of Quantum States: Bloch sphere representation - Pure and mixed states (intro) - Density matrix (basic concept).	4	["3"]
	3.3	Multi-Qubit Systems: Tensor product of states - Two-qubit systems - Introduction to entanglement (qualitative) - Measurement in composite systems.	4	["3"]
	3.4	Quantum Gates and Measurement: Basic quantum gates: Pauli (X, Y, Z) - Hadamard gate - State transformations - Measurement formalism.	3	["4"]
	3.5	Physical Realization and Limitations: No-cloning theorem (intro) - Decoherence (basic idea) - Physical implementations of qubits: Superconducting systems, Trapped ions, Photonic qubits.	3	["4"]
4	Quantum Computing Practical			
	4.1	1. Introduction to Quantum Simulator -Familiarization with platform, Running a simple circuit and observing outputs 2. Visualization of a Qubit State - Representing $\lvert 0>$ and $\lvert 1>$, Visualizing states on the Bloch sphere 3. Superposition using Hadamard Gate - Apply Hadamard gate to $\lvert 0\rangle$, Observe probabilistic measurement outcomes 4. Measurement Statistics - Perform repeated measurements, Verify probabilistic nature of quantum states 5. Implementation of Pauli Gates (X, Y, Z) - Apply gates on basis states, Study state transformations 6. Implementation of Z or phase gate	30	["5"]

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Tutorial, Group Discussion

Assessment Types	**MODE OF ASSESSMENT** Mode of Assessment: Both **A. Continuous Comprehensive Assessment (CCA)** **• Theory – 25 Marks** Assignments, Tutorials, Test paper, Seminar **• Practical – 15 Marks** Lab Involvement, Viva **B. End Semester Evaluation (ESE)** **• Theory – 50 Marks** Assessment Methods – Written Examination Duration of Examination – 2.00 Hrs Pattern of examination for Theory – Non-MCQ Different parts of written examination – Part - A , B Answer Type: ◦ PART - A ◦ Short answer - (10 out of 12) – 10 × 3 = 30 ◦ PART - B ◦ Short Essays/Problems - (2 out of 3) – 2 × 10 = 20 **• Practical – 35 Marks** Assessment Methods – Lab Exam - 30 marks, Record - 5 marks Duration of Examination – 2.00 Hrs

References

- Nielsen, M. A., & Chuang, I. L. (2010). Quantum Computation and Quantum Information: 10th Anniversary Edition. Cambridge: Cambridge University Press.

Suggested Readings

- Concepts of Modern Physics: Arthur Beiser, Mc Graw Hills
- Introduction to Quantum Mechanics: David, J Griffith, Prentice Hall
- An Introduction to Quantum Computing, Phillip Kaye, Raymond Laflamme, and Michele Mosca, Oxford University Press (2006)
- Quantum computing explained, David McMahon, Wiley (2008)
- Quantum Computing Mechanics, A. B. Bhattacharya, Khanna Publishing House (2025)

Affidavit

- We, Bishop Abraham Memorial College, Thuruthicaud and Ens Mathews, retain the copyright of this syllabus and expressly prohibit its distribution in complete form to any institution outside our own.
- We, Bishop Abraham Memorial College, Thuruthicaud, agree to appoint a new course coordinator for the proposed Quantum Computing in the event of the unavailability of the currently nominated coordinator. This appointment will ensure the continued coordination of course delivery, assessments, and all related academic responsibilities necessary for the successful implementation of the specialization, for as long as the college offers this programme.
- We, Bishop Abraham Memorial College, Thuruthicaud and Ens Mathews, declare that no part of this signature course submitted here for approval has been taken from the course content developed by, or from any of the course titles prepared by, the BoS/expert committee in the same discipline under our University.

SYLLABUS			
SIGNATURE COURSE			
Name of the College	Bishop Abraham Memorial College, Thuruthicaud		
Faculty/ Discipline	Physics		
Programme	BSc (Hons) Physics		
Course Coordinator	Ens Mathews		
Contributors			
Course Name	Introduction to Quantum Computing		
Type of Course	DSE		
Specialization title	Quantum Computing		
Course Code	MG4DSEPHYA05		
Course Level	200		
Course Summary	This course introduces the fundamental concepts of quantum computing with a strong emphasis on intuition and visualization. It covers basic quantum ideas such as superposition, measurement, and quantum states, followed by the representation and behavior of qubits using tools like the Bloch sphere. Students are introduced to simple quantum gates and circuits, along with their role in quantum computation. The course minimizes mathematical complexity while building conceptual understanding. A practical component using simulation tools complements the theory, enabling students to explore quantum systems hands-on and interpret results, thereby preparing them for advanced studies in quantum circuits, algorithms, and quantum information.		
Semester	4	**Credits**	4
Course Details			
Pre-requisites, if any	Students should have a basic background in higher secondary (Class XII) Physics and Mathematics.		

Course Details:

Learning Approach	**Lecture**	**Practical/Lab-P**	**Total Hours**
Credits	3	1	75

Course Outcomes (CO)

Number of COs		**4**	
CO No.	**Expected Course Outcome**	**Learning Domains ***	**PO No**
1	Explain basic quantum concepts such as superposition, measurement, and wave-particle duality.	U	PO1, PO2, PO3, PO4, PO10
2	Describe qubits, Bloch sphere representation, and simple multi-qubit systems.	U, A	PO1, PO2, PO3, PO4, PO10
3	Interpret basic quantum gates and simple quantum circuits conceptually.	A	PO1, PO2, PO3, PO4, PO10
4	Perform basic quantum simulations.	A	PO1, PO2, PO3, PO4, PO10

Remember (K), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)

CO-PO Articulation Matrix

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	3	3	3	2	-	-	-	-	-	1
CO 2	3	3	3	2	-	-	-	-	-	1
CO 3	3	3	3	2	-	-	-	-	-	1
CO 4	3	3	3	2	-	-	-	-	-	1

‘0’ is No Correlation, ‘1’ is Slight Correlation (Low level), ‘2’ is Moderate Correlation (Medium level) and ‘3’ is Substantial Correlation (High level).

Course Content

Content for Classroom transaction (Units)

Module	Units	Course Description	Hrs	CO No.
1	Foundations of Quantum Concepts			
	1.1	Classical vs Quantum Ideas: Limitations of classical computing (introductory) - Brief idea of classical bits - Failure of classical physics (qualitative) - Wave–particle duality.	5	["1"]
	1.2	Quantum States and Superposition: Concept of quantum state (intuitive) - Superposition principle - Probability amplitudes (conceptual) - Simple examples of superposition.	5	["1"]
	1.3	Measurement and Notation - Measurement in quantum systems - Probabilistic outcomes - Collapse of state (qualitative) - Introduction to Dirac notation.	5	["1"]
2	Qubits and Quantum States			
	2.1	Qubits and Representation: Classical bit vs qubit - Basis states $\vert 0\rangle$ and $\vert 1\rangle$ - Linear combination of states - Physical meaning of coefficients.	5	["2"]
	2.2	Bloch Sphere and Visualization: Bloch sphere representation (conceptual) - State visualization - Phase and its qualitative meaning.	5	["2"]
	2.3	Multi-Qubit Systems: Two-qubit systems (conceptual) - Tensor product (idea only) - Introduction to entanglement (qualitative) - Measurement in multi-qubit systems	5	["2"]
3	Quantum Gates and Circuits			
	3.1	Quantum Operations: Concept of quantum operations - State transformation (intuitive) - Unitary evolution (idea only).	5	["3"]
	3.2	Basic Quantum Gates: Pauli gates (X, Y, Z) – conceptual action - Hadamard gate - Effect of gates on qubit states.	5	["3"]
	3.3	Quantum Circuits and Applications: Representation of quantum circuits - Sequential gate operations - Simple circuit examples - Introductory idea of Deutsch algorithm - Overview of real quantum computing platforms.	5	["3"]

Module	Units	Course Description	Hrs	CO No.
4	Quantum Computing Practical			
	4.1	1. Effect of Sequential Gates - Apply multiple gates in sequence, Analyze final state. 2. Phase and Interference - Demonstrate phase changes using Z or phase gate, Observe interference effects. 3. Two-Qubit System - Construct two-qubit states, Observe combined system behaviour. 4. Creation of Entangled States - Generate Bell state using H and CNOT gates, Verify correlations in measurements. 5. Measurement in Multi-Qubit Systems - Perform measurement on entangled states, Study outcome correlations. 6. Simple Quantum Circuit Construction - Design a small circuit combining gates, Predict and verify output.	30	["4"]

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lectures, Demonstrations, Simulation-based learning, Group discussions

Assessment Types	**MODE OF ASSESSMENT** Mode of Assessment: Both **A. Continuous Comprehensive Assessment (CCA)** • **Theory – 25 Marks** Assignment, Seminar, Test Paper • **Practical – 15 Marks** Lab Involvement, Viva **B. End Semester Evaluation (ESE)** • **Theory – 50 Marks** Assessment Methods – Written Examination Duration of Examination – 2.00 Hrs Pattern of examination for Theory – Non-MCQ Different parts of written examination – Part - A , B Answer Type: ◦ PART - A ◦ Short answer - (10 out of 12) – 10 × 3 = 30 ◦ PART - B ◦ Short Essays/Problems - (2 out of 3) – 2 × 10 = 20 • **Practical – 35 Marks** Assessment Methods – Lab Exam - 30 marks, Record - 5 marks Duration of Examination – 2.00 Hrs

References

- Nielsen, M. A., & Chuang, I. L. (2010). Quantum Computation and Quantum Information: 10th Anniversary Edition. Cambridge: Cambridge University Press.

Suggested Readings

- Concepts of Modern Physics: Arthur Beiser, Mc Graw Hills
- Introduction to Quantum Mechanics: David, J Griffith, Prentice Hall
- An Introduction to Quantum Computing, Phillip Kaye, Raymond Laflamme, and Michele Mosca, Oxford University Press (2006)
- Quantum computing explained, David McMahon, Wiley (2008)
- Quantum Computing Mechanics, A. B. Bhattacharya, Khanna Publishing House (2025)

Affidavit

- We, Bishop Abraham Memorial College, Thuruthicaud and Ens Mathews, retain the copyright of this syllabus and expressly prohibit its distribution in complete form to any institution outside our own.
- We, Bishop Abraham Memorial College, Thuruthicaud, agree to appoint a new course coordinator for the proposed Quantum Computing in the event of the unavailability of the currently nominated coordinator. This appointment will ensure the continued coordination of course delivery, assessments, and all related academic responsibilities necessary for the successful implementation of the specialization, for as long as the college offers this programme.
- We, Bishop Abraham Memorial College, Thuruthicaud and Ens Mathews, declare that no part of this signature course submitted here for approval has been taken from the course content developed by, or from any of the course titles prepared by, the BoS/expert committee in the same discipline under our University.

SYLLABUS			
SIGNATURE COURSE			
Name of the College	Bishop Abraham Memorial College, Thuruthicaud		
Faculty/ Discipline	Physics		
Programme	BSc (Hons) Physics		
Course Coordinator	Ens Mathews		
Contributors			
Course Name	Quantum Circuits and Algorithms		
Type of Course	DSE		
Specialization title	Quantum Computing		
Course Code	MG5DSEPHYA05		
Course Level	300		
Course Summary	This course introduces the formal framework of quantum circuits and explores key quantum algorithms that demonstrate computational advantages over classical methods. It covers the quantum circuit model, single- and multi-qubit gates, and the concept of universal quantum computation. Students study important algorithms such as the Quantum Fourier Transform, phase estimation, and Grover’s search algorithm, along with their applications in problems like factoring and search. The course also provides an overview of quantum simulation and physical implementations of quantum computers. A practical component using simulation tools enables students to design and analyze quantum circuits, reinforcing both conceptual understanding and computational skills.		
Semester	5	**Credits**	4
Course Details			
Pre-requisites, if any	Students should have completed a foundational course in quantum computing such as Fundamentals/Introduction to Quantum Computing. They should be familiar with basic concepts of quantum mechanics, including quantum states, superposition, and measurement, as well as elementary linear algebra (vectors, matrices, and tensor products).		

Course Details:

Learning Approach	Lecture	Practical/Lab-P	Total Hours
Credits	3	1	75

Course Outcomes (CO)

Number of COs		4	
CO No.	**Expected Course Outcome**	**Learning Domains ***	**PO No**
1	Construct quantum circuits using single- and multi-qubit gates.	A	PO1, PO2, PO3, PO4, PO10
2	Analyze quantum algorithms such as Quantum Fourier Transform and phase estimation and interpret their applications in computational problems.	U, An	PO1, PO2, PO3, PO4, PO10

Number of COs		4	
CO No.	Expected Course Outcome	Learning Domains *	PO No
3	Analyze quantum search algorithms and explain their performance, limitations, and the principles underlying physical implementation of quantum computers.	An	PO1, PO2, PO3, PO4, PO10
4	Design and simulate quantum circuits and algorithms using appropriate quantum computing tools.	A	PO1, PO2, PO3, PO4, PO10

**Remember (K), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*

CO-PO Articulation Matrix

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	3	3	3	2	-	-	-	-	-	1
CO 2	3	3	3	2	-	-	-	-	-	1
CO 3	3	3	3	2	-	-	-	-	-	1
CO 4	3	3	3	2	-	-	-	-	-	1

‘0’ is No Correlation, ‘1’ is Slight Correlation (Low level), ‘2’ is Moderate Correlation (Medium level) and ‘3’ is Substantial Correlation (High level).

Course Content

Content for Classroom transaction (Units)

Module	Units	Course Description	Hrs	CO No.
1	Quantum Circuits and Gate Formalism			
	1.1	Quantum Circuit Model: Quantum circuit representation - Wires, gates, and measurement - Single-qubit gates (matrix form): X, Y, Z, H - Phase gates (S, T).	5	["1"]
	1.2	Multi-Qubit Gates: Tensor product (formal) - Controlled gates (CNOT, CZ, CU) - SWAP gate - Matrix representation of multi-qubit gates - Circuit representation of multi-qubit systems - Circuit identities and basic simplifications.	5	["1"]
	1.3	Universal Quantum Gates: Two-level unitary gates - Single-qubit + CNOT gates - Discrete universal gate sets - Approximation of arbitrary unitary operations (conceptual difficulty) - quantum computational complexity (qualitative).	5	["1"]
2	Quantum Algorithms and Simulation			
	2.1	Quantum Circuit Model – Advanced: Simulation of quantum systems - Quantum simulation algorithm (idea).	5	["2"]
	2.2	Quantum Fourier Transform & Phase Estimation: Quantum Fourier Transform (QFT) – circuit and concept - Phase estimation algorithm - Performance and requirements.	5	["2"]
	2.3	Applications of QFT: Order-finding problem - Factoring (idea behind Shor’s algorithm) - Period finding - Discrete logarithms (conceptual) - Hidden subgroup problem (introductory idea).	5	["2"]

Module	Units	Course Description	Hrs	CO No.
3	Quantum Search and Physical Realization			
	3.1	Quantum Search Algorithms: Grover's algorithm - Oracle and search procedure - Geometric visualization - Performance and optimality.	5	["3"]
	3.2	Extensions of Quantum Search: Quantum counting (idea) - Search as quantum simulation - Limits of black-box algorithms - NP-complete problems (concept)	5	["3"]
	3.3	Physical Realization of Quantum Computers: Conditions for quantum computation - Representation, unitary operations, measurement - Overview of implementations: Ion traps, Optical/photon systems, NMR and other schemes - Limitations and challenges.	5	["3"]
4	Quantum Circuits and Algorithms Lab (Qiskit-based)			
	4.1	1. Implementation of single-qubit gates (X, Y, Z, H) 2. Verification of matrix action of gates 3. Construction of multi-qubit states using tensor product 4. Implementation of CNOT and controlled gates 5. Creation and verification of Bell states 6. Simulation of SWAP gate and circuit equivalence 7. Quantum teleportation protocol simulation 8. Superdense coding implementation 9. Deutsch algorithm simulation 10. Deutsch–Jozsa algorithm simulation 11. Grover's search algorithm (small database)	30	["4"]

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lectures, Demonstrations, Simulation-based learning, Group discussions

Assessment Types	**MODE OF ASSESSMENT** Mode of Assessment: Both **A. Continuous Comprehensive Assessment (CCA)** • **Theory – 25 Marks** Assignment, Seminar, Test Paper • **Practical – 15 Marks** Lab Involvement, Viva **B. End Semester Evaluation (ESE)** • **Theory – 50 Marks** Assessment Methods – Written Examination Duration of Examination – 2.00 Hrs Pattern of examination for Theory – Non-MCQ Different parts of written examination – Part - A , B Answer Type: ∘ PART - A ∘ Short answer - (10 out of 12) – 10 × 3 = 30 ∘ PART - B ∘ Essays - (2 out of 3) – 2 × 10 = 20 • **Practical – 35 Marks** Assessment Methods – Lab Exam - 30 marks, Record - 5 marks Duration of Examination – 2.00 Hrs

References

- Nielsen, M. A., & Chuang, I. L. (2010). Quantum Computation and Quantum Information: 10th Anniversary Edition.

Cambridge: Cambridge University Press.

Suggested Readings

- Teja Marella, S., & Sai Kumar Parisa, H. (2022). Introduction to Quantum Computing. In Quantum Computing and Communications. IntechOpen. https://doi.org/10.5772/intechopen.94103
- N. David Mermin (2007). Quantum Computer Science - An Introduction, Cambridge: Cambridge University Press.
- Chris Bernhardt (2019). Quantum Computing for Everyone. The MIT Press, Cambridge.

Affidavit

- We, Bishop Abraham Memorial College, Thuruthicaud and Ens Mathews, retain the copyright of this syllabus and expressly prohibit its distribution in complete form to any institution outside our own.
- We, Bishop Abraham Memorial College, Thuruthicaud, agree to appoint a new course coordinator for the proposed Quantum Computing in the event of the unavailability of the currently nominated coordinator. This appointment will ensure the continued coordination of course delivery, assessments, and all related academic responsibilities necessary for the successful implementation of the specialization, for as long as the college offers this programme.
- We, Bishop Abraham Memorial College, Thuruthicaud and Ens Mathews, declare that no part of this signature course submitted here for approval has been taken from the course content developed by, or from any of the course titles prepared by, the BoS/expert committee in the same discipline under our University.

SYLLABUS			
SIGNATURE COURSE			
Name of the College	Bishop Abraham Memorial College, Thuruthicaud		
Faculty/ Discipline	Physics		
Programme	BSc (Hons) Physics		
Course Coordinator	Ens Mathews		
Contributors			
Course Name	Quantum Information		
Type of Course	DSE		
Specialization title	Quantum Computing		
Course Code	MG6DSEPHYA05		
Course Level	300		
Course Summary	This course introduces the principles of quantum information with emphasis on noise, information processing, and error correction in quantum systems. It covers quantum operations, common noise models, and methods for characterizing quantum states. Students learn basic quantum error correction techniques and explore key concepts of information theory, including entropy and data compression. The course also introduces quantum communication and cryptographic protocols such as quantum key distribution. Emphasis is placed on conceptual understanding with moderate mathematical treatment. A simulation-based practical component enables students to model noise effects, implement simple correction schemes, and analyze quantum information processes relevant to modern quantum technologies.		
Semester	6	**Credits**	4
Course Details			
Pre-requisites, if any	Completion of Fundamentals / Introduction to Quantum Computing and Quantum Circuits and Algorithms Knowledge of Qubits, basic gates, circuits, Linear algebra (vectors, matrices) and Basic probability		

Course Details:

Learning Approach	Lecture	Tutorial	Total Hours
Credits	3	1	60

Course Outcomes (CO)

Number of COs		**4**	
CO No.	**Expected Course Outcome**	**Learning Domains ***	**PO No**
1	Explain quantum noise, quantum operations, and analyze common noise models and distance measures for quantum states.	U, An	PO1, PO2, PO3, PO4, PO10
2	Describe the need for quantum error correction and analyze basic error correction codes and their limitations.	U, An	PO1, PO2, PO3, PO4, PO10
3	Interpret entropy, information measures, and fundamental quantum communication and cryptographic protocols.	An	PO1, PO2, PO3, PO4, PO10

Number of COs		4	
CO No.	**Expected Course Outcome**	**Learning Domains ***	**PO No**
4	Simulate quantum noise, error correction schemes, and quantum communication protocols using computational tools.	A	PO1, PO2, PO3, PO4, PO10

**Remember (K), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*

CO-PO Articulation Matrix

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	3	3	3	2	-	-	-	-	-	1
CO 2	3	3	3	2	-	-	-	-	-	1
CO 3	3	3	3	2	-	-	-	-	-	1
CO 4	3	3	3	2	-	-	-	-	-	1

'0' is No Correlation, '1' is Slight Correlation (Low level), '2' is Moderate Correlation (Medium level) and '3' is Substantial Correlation (High level).

Course Content

Content for Classroom transaction (Units)

Module	Units	Course Description	Hrs	CO No.
1	Quantum Noise and Operations			
	1.1	Classical and Quantum Noise: Classical noise and Markov processes (idea), Introduction to quantum operations, System–environment interaction (conceptual)	5	["1"]
	1.2	Quantum Operations Formalism: Operator-sum (Kraus) representation (basic idea), Trace and partial trace, Geometric picture for single qubit.	5	["1"]
	1.3	Noise Models and Distance Measures: Bit flip, phase flip, depolarizing channel, Amplitude and phase damping (conceptual), Introduction to distance measures - Trace distance (idea), Fidelity (concept).	5	["1"]
2	Quantum Error Correction			
	2.1	Error Correction: Sources of errors in quantum systems - Basic idea of error correction - Three-qubit bit flip code - Phase flip code.	5	["2"]
	2.2	Quantum Codes: Shor code (conceptual understanding) - Discretization of errors (idea) - Basic principles of quantum coding.	5	["2"]
	2.3	Limits and Practical Aspects: Limitations of error correction - Introductory idea of fault tolerance - Physical challenges in implementation.	5	["2"]
3	Quantum Information Theory			
	3.1	Entropy and Information: Shannon entropy, Von Neumann entropy, Conditional entropy and mutual information, Basic properties (qualitative only).	5	["3"]
	3.2	Quantum Information Concepts: Distinguishing quantum states (idea), Accessible information (conceptual), Data compression - Shannon theorem (idea), Schumacher theorem (conceptual).	5	["3"]
	3.3	Quantum Communication & Cryptography: Communication over quantum channels (idea) - Entanglement as a resource (introductory) - Quantum key distribution (BB84) - Basic ideas of quantum cryptography.	5	["3"]

Module	Units	Course Description	Hrs	CO No.
4	Simulation Tutorials			
	4.1	1. Simulation of noise channels (bit/phase flip) 2. Density matrix evolution under noise 3. Partial trace and subsystem analysis 4. Fidelity calculation for quantum states 5. Simulation of decoherence 6. Implementation of bit flip error correction code 7. Phase flip error correction simulation 8. Demonstration of simple quantum coding 9. Entropy calculation for quantum states 10. Simulation of BB84 protocol	15	["4"]

Teaching and Learning Approach	Classroom Procedure (Mode of transaction) Lectures, Demonstrations, Simulation-based learning, Group discussions

Assessment Types	**MODE OF ASSESSMENT** Mode of Assessment: Theory **A. Continuous Comprehensive Assessment (CCA)** • **Theory – 30 Marks** Assignment, Seminar, Test Paper **B. End Semester Evaluation (ESE)** • **Theory – 70 Marks** Assessment Methods – Written Examination Duration of Examination – 2.00 Hrs Pattern of examination for Theory – Non-MCQ Different parts of written examination – Part - A , B Answer Type: ◦ PART - A ◦ Short answer - (10 out of 12) – 10 × 5 = 50 ◦ PART - B ◦ Essays - (2 out of 3) – 2 × 10 = 20

References

- Nielsen, M. A., & Chuang, I. L. (2010). Quantum Computation and Quantum Information: 10th Anniversary Edition. Cambridge: Cambridge University Press.

Suggested Readings

- Pathak, A. (2013). Elements of Quantum Computation and Quantum Communication (1st ed.). CRC Press. https://doi.org/10.1201/b15007
- A. B. Bhattacharya (2025). Introduction to Quantum Communication. Khanna Publishing House.

Affidavit

- We, Bishop Abraham Memorial College, Thuruthicaud and Ens Mathews, retain the copyright of this syllabus and expressly prohibit its distribution in complete form to any institution outside our own.
- We, Bishop Abraham Memorial College, Thuruthicaud, agree to appoint a new course coordinator for the proposed Quantum Computing in the event of the unavailability of the currently nominated coordinator. This appointment will

ensure the continued coordination of course delivery, assessments, and all related academic responsibilities necessary for the successful implementation of the specialization, for as long as the college offers this programme.

- We, Bishop Abraham Memorial College, Thuruthicaud and Ens Mathews, declare that no part of this signature course submitted here for approval has been taken from the course content developed by, or from any of the course titles prepared by, the BoS/expert committee in the same discipline under our University.