MathematicalMethodsfor Quantum Technologies			
Course Code	1MQT101	Scheme	2026
Type of Course	**PCC**	Semester	I
Teaching Hours/Week (L: T:P)	3: 2:0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	120 Hours (L:42, T:28, P:0, TW+SL:50)	SEE Marks	50
Credits	**4 Credit**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. Apply complex algebra, vector space concepts, advanced linear algebra, and matrix methods to represent and manipulate quantum states and solve eigen-value problems.
2. Formulate and solve Ordinary and Partial Differential Equations (ODEs/PDEs) to model physical quantum hardware systems.
3. Apply probability, statistics, and noise characterization techniques to model real-world decoherence and thermal fluctuations in open quantum systems.
4. Translate abstract mathematical models into simulated physical environments.

Module-1

Complex Algebra and Vector Spaces: Brief review of Complex algebra, complex numbers - real and imaginary parts, Argand plane. Polar representation, Euler's formula, complex conjugates, and modulus. Introduction to Hilbert spaces, inner products, and orthogonality.

Number of Hours: 08

Module-2

Linear Algebra and Matrix Techniques: Vector spaces, linear independence, basis, and dimension. Matrices, determinants, inverse, trace. Hermitian, Unitary, and Projection operators. Eigenvalues and Eigenvectors, Spectral theorem, diagonalization, and Tensor products. Applications of linear algebra to quantum mechanics (Operators representing observables).

Number of Hours:08

Module-3

Ordinary Differential Equations (ODEs): Ordinary differential equations and initial value problems. First-order and second-order linear ODEs with constant and variable coefficients. Series solutions.Applications of ODEs: The classical harmonic oscillator, driven harmonic oscillator, and damped harmonic oscillator. Transition to anharmonic oscillators (concept of transmon qubits).

Number of Hours:09

Module-4

Partial Differential Equations (PDEs): Partial differential equations and boundary value problems. Separation of variables technique. Applications of PDEs: The 1D and 3D wave equations. Electromagnetic waves in vacuum and dielectric media, waveguides, and resonant cavities.

Number of Hours:08

Module-5

Probability, Statistics, and Noise: Probability: Random Variables, discrete and continuous probability distributions. Gaussian Random variables – Law of large numbers, Central Limit Theorem.Statistical Physics Applications: Gibbs principle, computing average thermal energy, and partition functions.Noise Characterization: Thermal fluctuations, Johnson-Nyquist noise, noise, and Markov processes.

Number of Hours:09

Suggested Learning Resources: (Textbook/ Reference Book/ Manuals):

1. Erwin Kreyszig, Advanced Engineering Mathematics, 10th Edition, Wiley.
2. Arfken, Weber, and Harris, Mathematical Methods for Physicists, 7th Edition, Elsevier.
3. Introduction to Quantum Mechanics, Griffiths D. J., 3rd Edition, Cambridge University Press (2024)
4. Principles of Quantum Mechanics, Shankar, R., 2nd edition, Springer (2014)
5. Quantum Information Science – Manenti R., Motta M., 1st Edition, Oxford University Press (2023)
6. Quantum computation and quantum information – Nielsen M. A., and Chuang I. L., 10th Anniversary edition, Cambridge University Press (2010) A Pathak, Elements of Quantum Computation and Quantum Communication, Boca Raton, CRC Press (2015)

Web links and Video Lectures (e-Resources):

https://www.youtube.com/watch?v=XNaWV8VNwM0
https://www.youtube.com/watch?v=1LubzKrjr68&list=PLbMVogVj5nJQ2vsW_hmyvVfO4GYWaaPp7&index=2
https://www.youtube.com/watch?v=sxzFpOsvfgU
https://www.youtube.com/watch?v=8kcvyoHsXrw
https://www.youtube.com/watch?v=zujeSyREcQ4

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- ICT-Enabled Teaching
- Simulation and Virtual Labs
- Think-Pair-Share

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the CIE, a student must score at least 40% of 50 marks, i.e., 20 marks.
- To pass the SEE, a student must score at least 35% of 50 marks, i.e., 18 marks.
- Notwithstanding the above, a student is considered to have passed the course, provided the combined total of CIE and SEE is at least 40 out of 100 marks.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal EvaluationCIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.
In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.
It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1.	Case Study Presentation	10
2.	Programming Assignment	15

	Superior (9-10)	Good (7-8)	Fair (5-6)	Needs Improvement (3-4)	Unacceptable (0-2)
Case based Presentation					
Integration of Quantum Apps (CO4)	Demonstrates a profound link between the chosen case and quantum tech	Clearly explains the quantum application with minor conceptual gaps.	Mentions quantum context but focuses mostly on general theory.	Weak or incorrect link between math and quantum technology.	No mention of quantum technology applications.
Modeling via ODEs/PDEs (CO2)	Flawless setup and solution of differential equations for the physical system.	Correct use of DEs with minor errors in boundary conditions.	Uses DEs correctly but fails to interpret the physical solution.	Significant errors in setting up or solving the required equations.	Incorrect mathematical methods used for the physical model.
Technical Communication	Professional delivery; high-quality visuals; precise technical vocabulary.	Clear communication; logical flow; handles Q&A effectively.	Understandable but relies heavily on slides; basic responses in Q&A.	Poor organization; difficult to follow the technical argument.	Incoherent presentation or lacks required materials.

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours /

		Semester
1.	Case Study Preparation: Researching and documenting the application of Differential Equations in Quantum Harmonic Oscillators.	5
2.	Programming Exercises: Numerical implementation of Matrix methods and Linear Algebra using Python/NumPy.	10
3.	Technical Seminar: Presentation on Noise Characterization and Gaussian Random Variables in quantum systems.	5
4.	Problem Sets: Submission of advanced tutorial sheets covering Complex Algebra and PDE boundary value problems.	10
	Total	30

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1.	**MOOCs:** Completing certified modules on "Linear Algebra for Quantum Computing" (e.g., via NPTEL, Coursera, or EdX).	5
2.	**Spoken Tutorials:** Learning Scilab or Python for solving Ordinary and Partial Differential Equations.	5
3.	**Online Resources:** Studying NIST standards for noise analysis and quantum-resistant mathematical structures.	5
4.	**Independent Study:** Reviewing Gibbs Principle and thermal fluctuations using specialized digital library resources.	5
		20

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Principlesofquantummechanics

Course Code	1MQT102	Scheme	2026
Type of Course	**PCC**	Semester	I
Teaching Hours/Week (L: T:P)	3: 0: 0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90 Hours (L:42, T:0, P:0, TW+SL:48)	SEE Marks	50
Credits	**3 Credit**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. Understand the basic postulates of quantum mechanics, apply Dirac Bra-Ket notation, and solve 1D potential problems for basic quantum systems.
2. Apply approximation techniques, such as perturbation theory and variational techniques, to complex systems.
3. Utilize density operator formalism to represent mixed states and grasp the basic dynamics of open quantum systems.
4. Analyze foundational quantum phenomena, particularly entanglement, using software and hardware models.

Module-1

Postulates and Mathematical Framework: Postulates of Quantum Mechanics. The wave function and its interpretation. Observables and operators. The Schrödinger equation. Dirac Bra-Ket notation: state vectors, dual spaces, and inner products. Projection operators and measurement probabilities.

Number of Hours: 09

Module-2

1D Potentials and Approximation Methods:1D potential problems: the infinite square well (particle in a box), finite potential well, and barrier penetration (quantum tunneling). Harmonic oscillator via ladder operators. Approximation techniques: Time-independent perturbation theory (non-degenerate), variational techniques.

Number of Hours: 09

Module-3

Angular Momentum and Identical Particles: Orbital angular momentum and spin. Angular momentum algebra and commutation relations. Addition of angular momenta. Identical particles: symmetric and antisymmetric wave functions. Pauli exclusion principle. Bosons and Fermions.

Number of Hours: 08

Module-4

Density Operators and Open Systems: Density operator formalism for pure and mixed states. Properties of the density matrix (Trace, Positivity). The Bloch sphere representation of mixed states. Limitations of closed quantum systems. Introduction to open quantum systems: decoherence, relaxation (T_1and T_2times), and the Lindblad master equation (conceptual overview).

Number of Hours: 08

Module-5

Foundational Issues and Entanglement: Foundational issues in quantum mechanics. The EPR paradox. Bell's inequalities and the violation of local realism. Quantum entanglement: definition and mathematical representation (bipartite systems, Schmidt decomposition). Introduction to quantum teleportation concepts.

Number of Hours: 08

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. **Griffiths, D. J., *Introduction to Quantum Mechanics*, 3rd Edition, Cambridge University Press (2024).**
2. **Shankar, R., *Principles of Quantum Mechanics*, 2nd Edition, Springer (2014).**
3. **Nielsen, M. A., & Chuang, I. L., *Quantum Computation and Quantum Information*, 10th Anniversary Edition, Cambridge University Press (2010).**
4. **Quantum Information Science – Manenti R., Motta M., 1st Edition, Oxford University Press (2023)**

5. **A Pathak, Elements of Quantum Computation and Quantum Communication, Boca Raton, CRC Press (2015)**

Web links and Video Lectures (e-Resources):

https://www.youtube.com/watch?v=IKJAJdDEqhM&t=657s
https://www.youtube.com/watch?v=r2NMWEsNcTs

https://www.youtube.com/watch?v=vy-qStGSy0g

https://www.youtube.com/watch?v=iW-k3Hphbh4&list=PLwdnzlV3ogoUfI5wrKOiYVTThdFAriFji

https://www.youtube.com/watch?v=9lX2FENOe4o

Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- ICT-Enabled Teaching
- Simulation and Virtual Labs
- Think-Pair-Share

Assessment Structure:
The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the CIE, a student must score at least 40% of 50 marks, i.e., 20 marks.
- To pass the SEE, a student must score at least 35% of 50 marks, i.e., 18 marks.
- Notwithstanding the above, a student is considered to have passed the course, provided the combined total of CIE and SEE is at least 40 out of 100 marks.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal EvaluationCIE [25+25=50 marks]
A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.
In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.
It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
3.	Case Study Presentation	10
4.	Tool/Software Exploration	15

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1.		
2.		
3.		
4.	(Add rows if required)	

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1.		
2.		

3.		
4.	(Add rows if required)	

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

Classical and Quantum Information Theory

Course Code	1MQT103	Scheme	2026
Type of Course	**PCC**	Semester	I
Teaching Hours/Week (L: T:P)	3:0: 0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90 Hours (L:42, T:0, P:0, TW+SL:48)	SEE Marks	50
Credits	**3 Credit**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. Grasp the fundamentals of classical information theory, specifically Shannon entropy and channel encoding.
2. Formulate and analyze quantum information metrics, particularly von Neumann entropy and measures of entanglement.
3. Understand the mathematical constraints of quantum channel capacity and the No-Cloning Theorem.
4. Compare heuristic ideas of classical networks with the architecture of Quantum Networks and Quantum Repeaters.

Module-1

Classical and Quantum Information Theory: Basics of classical information theory. Concept of information, self-information, and Shannon entropy. Properties of Shannon entropy. Joint entropy, conditional entropy, and mutual information. Data compression: Shannon's noiseless coding theorem. Huffman coding and Shannon-Fano coding (brief overview).

Number of Hours: 08

Module-2

Noisy Channels and Error Correction: Noisy channel encoding. Discrete memoryless channels (DMC). Binary symmetric channel (BSC) and binary erasure channel (BEC). Channel capacity. Shannon's noisy channel coding theorem. Introduction to classical error correction codes: parity checks, Hamming codes.

Number of Hours: 08

Module-3

Quantum Information Basics: Transition from classical to quantum information. The density matrix as a tool for quantum information. von Neumann entropy: definition, mathematical properties (Subadditivity, Strong subadditivity, Triangle inequality). Relative entropy and quantum mutual information.

Number of Hours: 09

Module-4

Entanglement and Channel Capacity: Entanglement as a resource. Measures of entanglement (Entropy of entanglement for pure bipartite states, Negativity, Concurrence). Quantum channel capacity: Holevo bound and Accessible Information. The No-Cloning Theorem and its proof.

Number of Hours: 09

Module-5

Networks and Communication Protocols: Heuristic ideas of classical networks (nodes, routers, classical fibre). Transition to Quantum Networks: the role of entanglement distribution. The necessity of Quantum Repeaters and entanglement swapping. Foundational Quantum Communication Protocols: Superdense Coding and Quantum Teleportation.

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text Book

1. **Nielsen, M. A., & Chuang, I. L., *Quantum Computation and Quantum Information*, 10th Anniversary Edition, Cambridge University Press (2010).**
2. **Wilde, Mark M., *Quantum Information Theory*, 2nd Edition, Cambridge University Press (2017).**
3. **Manenti R., Motta M., *Quantum Information Science*, 1st Edition, Oxford University Press (2023).**
4. **A Pathak, Elements of Quantum Computation and Quantum Communication, Boca Raton, CRC Press**

(2015)

Web links and Video Lectures (e-Resources):

https://www.youtube.com/watch?v=TJtUYtWU89Q

https://www.youtube.com/watch?v=i4nFvaJibEM&list=PLFxYlZrPtZWzMTf-LKF0BrY25F9KEhCFy&index=18

https://www.youtube.com/watch?v=zHMDUjDnZc0

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- ICT-Enabled Teaching
- Simulation and Virtual Labs
- Think-Pair-Share

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the CIE, a student must score at least 40% of 50 marks, i.e., 20 marks.
- To pass the SEE, a student must score at least 35% of 50 marks, i.e., 18 marks.
- Notwithstanding the above, a student is considered to have passed the course, provided the combined total of CIE and SEE is at least 40 out of 100 marks.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal EvaluationCIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
5.		
6.		

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
  Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
5.		
6.		
7.		
8.	(Add rows if required)	

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1.		

2.		
3.		
4.	(Add rows if required)	

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

Programming for Quantum Technologies

Course Code	1MQTL104	Scheme	2026
Type of Course	**PCCL**	Semester	I
Teaching Hours/Week (L: T:P)	0: 0: 4	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	60 Hours (L:0, T:0, P:56, TW+SL:04)	SEE Marks	50
Credits	**2 Credit**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. Understand and apply the fundamentals of classical programming (Python, Julia) for scientific computing and algorithm design.
2. Formulate and execute quantum assembly language (OpenQASM) to define low-level hardware instructions.
3. Utilize major quantum software frameworks (Qiskit, Cirq, PennyLane, Q-Omni) to build and deploy quantum circuits.
4. Model closed and open quantum system dynamics mathematically using specialized toolboxes.

Module-1

Classical Programming & Algorithmic Foundations: Basics of programming and data structures (arrays, lists, dictionaries, graphs). Fundamental algorithms: sorting and searching. Transitioning from classical logic to quantum oracles. Basics of Python programming for scientific computing.

Number of Hours: 12

Module-2

Scientific Computing with Python: Basics of Python for high-performance numerical analysis. Handling complex matrices, eigenvalues, and tensor products efficiently. Mapping classical array manipulation to quantum state vector representations.

Number of Hours: 10

Module-3

Quantum Assembly and Low-Level Logic: Basics of OpenQASM (Quantum Assembly Language). Defining registers (quantum and classical), applying fundamental gates, and executing measurements at the machine level.

Number of Hours: 12

Module-4

Advanced Quantum Frameworks (Qiskit, Cirq, PennyLane): Introduction to high-level Software Development Kits (SDKs). Building parameterized circuits, executing variational algorithms, and understanding hardware-agnostic compilation.

Number of Hours: 12

Module-5

Simulating Quantum Systems & Decoherence: Simulations of simple closed and open quantum systems. Introduction to QuTiP (Quantum Toolbox in Python). Defining Hamiltonians, collapse operators, and solving the Lindblad master equation programmatically.

Number of Hours: 10

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

1. **Downey, Allen B., *Think Python: How to Think Like a Computer Scientist*, 2nd Edition, O'Reilly (2015).**
2. **Johansson, J. R., Nation, P. D., & Nori, F., *QuTiP: Quantum Toolbox in Python*, Documentation & Tutorials.**
3. **IBM Quantum, *Qiskit Textbook* (Interactive Online Edition), 2024.**
4. **CUDA-Q https://nvidia.github.io/cuda-quantum/latest/index.html**
5. **Official python tutorial: https://docs.python.org/3/tutorial/index.html**
6. **Think Python: How to Think Like a Computer Scientist, 2nd edition, Allen B. Downey (O'Reilly, 2015)**

Web links and Video Lectures (e-Resources):

https://www.youtube.com/playlist?list=PLgMDNELGJ1CYS-8dlMGPIaowVfeda4nUj

https://www.youtube.com/watch?v=82v41gliAJE

https://www.youtube.com/playlist?list=PLwdnzlV3ogoXjqhoLuZIICaNBgmD8V72W

https://www.youtube.com/watch?v=9f_ppJG8FTM

https://nptel.ac.in/courses/106105082

https://www.youtube.com/watch?v=JZFK4jr3c7M&list=PLCTGenrx1-SOC-b98RCC1uEGI-Sc-N3C-

Teaching-Learning Process (Innovative Delivery Methods):

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- ICT-Enabled Teaching
- Simulation and Virtual Labs
- Think-Pair-Share

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the CIE, a student must score at least 40% of 50 marks, i.e., 20 marks.
- To pass the SEE, a student must score at least 35% of 50 marks, i.e., 18 marks.
- Notwithstanding the above, a student is considered to have passed the course, provided the combined total of CIE and SEE is at least 40 out of 100 marks.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal EvaluationCIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
7.		
8.		

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
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Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
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- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
9.		
10.		
11.		
12.	(Add rows if required)	

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
5.		
6.		

7.		
8.	(Add rows if required)	

Continuous Internal Evaluation (CIE)
(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE
For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Quantum Technology Lab 1		Scheme	2026
Course Code	**1MQTL105**	Semester	I
Teaching Hours/Week (L: T:P)	0: 0: 4	CIE Marks	50
Total Hours of Pedagogy L:T:P:SL/TW	60 Hours (L:0, T:0, P:56, TW+SL:04)	SEE Marks	50
Credits	**2 Credit**	Total Marks	100
Examination type (SEE)	**Practical**	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. Construct and verify foundational digital and analog circuits critical for quantum hardware control systems.
2. Execute physical optical experiments to observe polarization, classical interference, and diffraction using specialized photonics kits.
3. Validate fundamental quantum phenomena and set up optical interferometers to measure phase shifts and coherence.
4. Bridge theoretical quantum mechanics to physical reality by combining digital simulations with hands-on hardware execution.

Note:

1. **The laboratory syllabus consists of PART-A and PART-B.** While PART-A has 6 conventional/fixed experiments, PART-B has open-ended experiments.
2. The maximum marks for the laboratory course are 100. Both PART-A and PART-B are considered for CIE and SEE.
3. **SEE Execution:** Students have to answer 1 (one) question from PART-A and 1 (one) question from PART-B.
4. The questions set for SEE shall be from among the experiments under PART-A, evaluated for 70 marks. The open-ended question set for SEE shall be evaluated for 30 marks.
5. **CIE Execution:** For Continuous Internal Evaluation (CIE) during the semester, classwork shall typically include open-ended questions from Part-B, along with other similar questions designed to enhance the students' skills.

PART – A

FIXED SET OF EXPERIMENTS

1. Digital Electronics – Quantum Control Logic (Hardware Focus: FPGA Simulators / Basic Logic Gates)

- *Objective:* Understand the classical logic gates that form the basis of quantum control processors (precursors to the FPGA systems used in the *Synapse Q-Core* and *Apex Suite*).

  i. Combinational circuits:

  a. Half and Full Adder

  b. Decoder and Encoder

  ii. Sequential circuits:

  a. Flipflops and Shift Registers

2. Analog Electronics – RF & Readout Foundations

- *Objective:* Understand the behavior of analog signals, establishing the foundation for microwave qubit drive and readout lines.

  i. RLC filters (Mapping to LC Resonators):

  a. Frequency domain modeling of RLC circuits

  b. Low pass and high pass characteristics

  c. Quality Factor (Q)

  ii. Diode Circuits:

  a. Rectification and Envelope Detection

  iii. Op Amp circuits:

  a. Inverting and Non-inverting amplifiers

  b. Adder circuits

3. Simple Experiments Demonstrating Quantum Nature

- *Objective:* Historical, physical validation of quantum mechanics.
  i. Franck-Hertz Experiment (Quantization of energy levels)
  ii. Photoelectric effect (Particle nature of light)
  iii. Balmer lines (Atomic spectra)
  iv. Compton scattering
  v. Band gap of semiconductors

4. Basics of Optical Bench & Linear Optical Elements (Hardware: Quantangle Lumen Spark / Zenith Photonics)

- *Objective:* Hands-on alignment and manipulation of photons for discrete-variable encoding on a physical optical bench.
  i. Beam splitters (Creating spatial superposition)
  ii. Polarizers, Half-wave plates (HWP), and Full-wave plates (Manipulating photon spin/polarization states)
  iii. Diffraction gratings

5. Michelson Interferometer on an Optical Bench (Hardware: Quantangle Lumen Spark / Zenith Photonics)

- *Objective:* Measure the wavelength of a light source and observe longitudinal phase shifts, a precursor to complex interferometric sensing.

6. Mach-Zehnder Interferometer (Hardware: Quantangle Lumen Spark / Zenith Photonics)

- *Objective:* Construct an MZI to demonstrate classical and early quantum interference, laying the groundwork for understanding quantum phase interference and delayed-choice experiments.

PART – B
OPEN ENDED EXPERIMENTS

Open-ended experiments are a type of laboratory activity where the outcome is not predetermined and students are given the freedom to explore, design, and conduct the experiment based on the problem statements as per the concepts defined by the course coordinator. It encourages creativity, critical thinking, and inquiry-based learning.

Sample Problem Statements (Targeting the foundational physics of the Apex Quantum Suite):

1. **Analog Qubit Readout Simulation:** Design a classical Low-Pass RLC filter. Introduce a variable capacitor to simulate the dispersive shift of a qubit state, and measure the resulting shift in the resonant frequency, mimicking the basic principles of Transmon readout.
2. **Optical State Preparation & Verification:** Using the *Lumen Spark* kit (or equivalent), design an optical setup that takes a horizontally polarized laser beam, converts it into a circularly polarized beam, and then splits it based on orthogonal polarization states. Prove the transformation mathematically and verify it physically.
3. **Phase Stability in Interferometry:** Design an experiment using the Mach-Zehnder interferometer to introduce a known, controlled phase shift (e.g., using a glass slide or a thermal gradient in one arm) and characterize the resulting fringe shift to determine the sensitivity of the setup.

Course References:

1. Boylestad, R. L., & Nashelsky, L., *Electronic Devices and Circuit Theory*, 11th Edition, Pearson.
2. Lipson, S. G., *Optics Experiments and Demonstrations for Student Laboratories*, IOP Series in Emerging Technologies in Optics and Photonics.
3. Saleh, B. E. A., & Teich, M. C., *Fundamentals of Photonics*, 3rd Edition, Wiley (2019).
4. Quantangle Research Labs, *Lumen Spark, Zenith Photonics, & Apex Quantum Suite Laboratory Execution Manuals*.
5. ELECTRONIC DEVICES AND CIRCUIT THEORY,Boylestad / Nashelsk, Pearson Publication
6. Optics Experiments and Demonstrations for Student Laboratories: Principles, methods and applications (IOP Series in Emerging Technologies in Optics and Photonics), Professor Stephen G Lipson, Part of: IOP Series in Emerging Technologies in Optics and Photonics

7. Fundamentals of Photonics, Bahaa E. A. Saleh, Malvin Carl Teich, 2 Volume Set, 3rd Edition, , ISBN: 978-1-119-50687-4

Web links and Video Lectures (e-Resources):

Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.
1.ICT enabled teaching
2.Simulation and Virtual Labs
3.Tools/software exploration

Assessment Structure:
The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE marks awarded shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. Total marks for the all report shall be scaled down to 30 marks. The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and Marks scored shall be scaled down to 20 marks. Final average of marks for report and test shall be out of 50 marks.
For both CIE and SEE, the student is required to conduct one experiment each from both Part A and Part B.

Rubrics for CIE – Continuous assessment:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

- To qualify and become eligible to appear for SEE, in the **CIE component**, a student must secure **a minimum of 40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE component**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks**.
- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

Rubrics suggested for Practical continuous assessment

Performance Indicators	**Excellent**	**Very Good**	**Good**	**Satisfactory**
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
Implementation (8) (PO3 & PO8)	Student is capable of implementing the design with best suitable algorithm considering optimal solution. (7-8)	Student is capable of implementing the design with best suitable algorithm and should be capable of explaining it (5-6)	Student is capable of implementing the design with proper explanation. (3-4)	Student is capable of implementing the design. (1-2)
Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result with proper analysis. (5)	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyze the output. (3)	Student will be able to run the program but not able to analyze the

				output. (1-2)
Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

Note: Can add Engineering & IT tool usage based on the nature of the course

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Design and Synthesis of AI-Driven Quantum Algorithms using Q-Space: Quantum CircuitComposer

Course Code	1MQT106A	Scheme	2026
Type of Course	**IPCC**	Semester	I
Teaching Hours/Week (L:T:P)	3: 0: 2	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	120 Hours (L:42, T:0, P:28, TW+SL:50)	SEE Marks	50
Credits	**4 Credit**	Total Marks	100
Examination type (SEE)	Theory + Practical	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. Master the Q-Space Quantum Circuit Composer (QCC) interface for algorithm design and formulate foundational quantum algorithms.
2. Apply variational and heuristic algorithms to optimization problems, leveraging Q-Space's AI-assisted parameterization.
3. Understand quantum complexity classes and evaluate algorithm performance against classical benchmarks using the Q Omni backend.
4. Implement basic quantum error correction and fault-tolerant structures within the QCC, analyzing fidelity under simulated physical constraints.

Module-1

Introduction to Q-Space QCC and Algorithmic Foundations: Methods and tools in Q-Space: QCC**,** Qubits versus classical bits. Universal quantum logic gates and circuit representation. Review of Turing machines and classical computational complexity (Time and space complexity: P, NP, PSPACE). Quantum complexity classes (Q, EQP, BQP, BPP, QMA).

Number of Hours: 08

Module-2

Foundational Quantum Algorithms: The concept of quantum parallelism and phase kickback. Oracle-based algorithms: Deutsch algorithm, Deutsch-Jozsa algorithm, Bernstein-Vazirani algorithm, and Simon's algorithm.

Number of Hours: 09

Module-3

Quantum Search and Prime Factorization: Database search mechanics. Amplitude amplification. Grover's search algorithm. The Quantum Fourier Transform (QFT). Period finding. Shor's Algorithm for prime factorization.

Number of Hours: 09

Module-4

Advanced and Variational Algorithms: Transition to NISQ-era algorithms. Variational Quantum Eigensolver (VQE) for molecular energies. Quantum Approximate Optimization Algorithm (QAOA) for combinatorial optimization. Harrow-Hassidim-Lloyd (HHL) algorithm for solving linear systems of equations.

Number of Hours: 08

Module-5

Error Correction and Fault Tolerance: The necessity of error correction. Classical vs. Quantum error correction. Bit-flip and phase-flip codes. The Shor 9-qubit code. Introduction to fault-tolerant computing and stabilizer codes.

Number of Hours: 08

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

1. **1. Nielsen, M. A., & Chuang, I. L., *Quantum Computation and Quantum Information*, 10th Anniversary Edition, Cambridge University Press (2010).**
2. **Mermin, N. D., *Quantum Computer Science: An Introduction*, Cambridge University Press (2007).**
3. **Lipton, R. J., and Regan, K. W., *Introduction to Quantum Algorithms via Linear Algebra*, MIT Press (2021).**

Web links and Video Lectures (e-Resources):

https://www.youtube.com/watch?v=nQAbbUYA93k

https://www.youtube.com/watch?v=WeXuMevXbFo&list=PLLy_2iUCG87C0Jd38EnIXPtfUW3TMCHfz

Laboratory Programs:

1. Design and simulate classical reversible logic gates (e.g., Toffoli gate acting as an AND gate) using quantum equivalents.
2. Construct quantum circuits to generate various Bell states and analyze state vectors and Bloch sphere phase rotations.
3. Implement the Deutsch-Jozsa algorithm for a 2-qubit system and verify the deterministic identification of constant versus balanced functions.
4. Define a hidden mathematical function \$f(x)\$ and synthesize the N-qubit oracle circuit for the Bernstein-Vazirani algorithm.
5. Implement Grover's algorithm for a 3-qubit database search and plot the step-by-step amplitude amplification.
6. Construct a 3-qubit and 4-qubit Quantum Fourier Transform (QFT) circuit and analyze the resulting phase shifts.
7. Implement a Variational Quantum Eigensolver (VQE) algorithm to find the ground state energy of a simple Hamiltonian (e.g., for an \$H_2\$ molecule).
8. Set up a Quantum Approximate Optimization Algorithm (QAOA) for a basic graph Max-Cut problem and analyze the probability distributions of the solutions.
9. Design a 3-qubit bit-flip error correction circuit using auxiliary (ancilla) qubits and parity measurement.
10. Simulate a quantum circuit under environmental noise (thermal noise/bit-flip errors) and demonstrate successful state recovery using syndrome measurement logging.

Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- **Software-Centric Delivery:** The theoretical explanation of algorithms (like Grover's) is immediately followed by hands-on construction within the QCC, allowing students to visualize amplitude amplification dynamically rather than purely mathematically.
- **AI-Assisted Synthesis:** Leveraging the QCC Utility Mode to abstract complex oracle generation, allowing students to focus on algorithmic inputs and results rather than getting bogged down in manual gate alignment for large-scale algorithms.

Assessment Structure:
The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the CIE, a student must score at least 40% of 50 marks, i.e., 20 marks.
- To pass the SEE, a student must score at least 35% of 50 marks, i.e., 18 marks.
- Notwithstanding the above, a student is considered to have passed the course, provided the combined total of CIE and SEE is at least 40 out of 100 marks.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal EvaluationCIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.
In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.
It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
9.		
10.		

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to): - Course Project - Case Study Presentation - Programming Assignment - Tool/Software Exploration - Literature Review - Open Book Test (preferably at RBL4 and RBL5 levels) - GATE-based Aptitude Test - Assignment (at RBL3, RBL4, or RBL5 levels) - Any other relevant and innovative academic activity Use of MOOCs and Online Platforms
Suggested Innovative Delivery Methods may include (but are not limited to): - Flipped Classroom - Problem-Based Learning (PBL) - Case-Based Teaching - Simulation and Virtual Labs - Partial Delivery of course by Industry expert/ industrial visits - ICT-Enabled Teaching - Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
13.		
14.		
15.		
16.	(Add rows if required)	

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
9.		
10.		
11.		
12.	(Add rows if required)	

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Classical and Quantum-Assisted Machine Learning			
Course Code	1MQT106B	Scheme	2026
Type of Course	**IPCC**	Semester	I
Teaching Hours/Week (L:T:P)	3: 0: 2	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	120 Hours (L:42, T:0, P:28, TW+SL:50)	SEE Marks	50
Credits	**4 Credit**	Total Marks	100
Examination type (SEE)	Theory + Practical	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. Understand foundational statistical approaches and differentiate between classical learning models and their generative AI counterparts.
2. Formulate quantum counterparts to classical models, such as Quantum Support Vector Machines and Quantum Neural Networks.
3. Utilize quantum simulation platforms to parameterize and execute Quantum-Assisted Machine Learning algorithms.
4. Evaluate specific use cases to identify where quantum assistance provides a theoretical computational advantage.

Module-1

Foundations of Classical Machine Learning: Basic statistical approaches: regression, classification. Learning models: Supervised and Unsupervised learning. Support vector machines (SVM). Feedback and Back propagation. Predictive models.

Number of Hours: 08

Module-2

Advanced Neural Networks and AI paradigms: Neural network approaches: Recurrent Neural Networks (RNN), Convolutional Neural Networks (CNN), Graph Neural Networks (GNN), k-Nearest Neighbors (KNN). Introduction to Reinforcement learning. Deep learning architectures. Generative AI (with specific attention to content generation). Agentic AI.

Number of Hours: 08

Module-3

Quantum Counterparts to Classical Models (QML): Transitioning data into quantum states (feature mapping / data encoding). Quantum Support Vector Machine (QSVM). The Quantum kernel trick. Quantum back propagation.

Number of Hours: 09

Module-4

Quantum Neural Networks (QNNs): Architecture of Parameterized Quantum Circuits (PQCs) as neural network layers. Quantum RNNs. Quantum Convolutional Neural Networks (QCNN). Hybrid quantum-classical optimization loops.

Number of Hours: 09

Module-5

Use Cases and Applications of QML: Analyzing the computational bottlenecks in classical ML and the theoretical advantages of QML. Specific use cases: Image analysis, Image recognition, Facial recognition, Voice recognition, Computer vision, Character recognition, Weather forecasting, and Satellite imaging.

Number of Hours: 08

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

1. **Schuld, Maria, and Petruccione, Francesco, *Supervised Learning with Quantum Computers*, Springer Publishing Company (2018).**
2. **Bishop, Christopher M., *Pattern Recognition and Machine Learning*, Springer (2006).**
3. **Wittek, P., *Quantum Machine Learning: What Quantum Computing Means to Data Mining*, Academic Press**

(2014).

Web links and Video Lectures (e-Resources):

https://www.youtube.com/watch?v=nQAbbUYA93k

https://www.youtube.com/watch?v=WeXuMevXbFo&list=PLLy_2iUCG87C0Jd38EnIXPtfUW3TMCHfz

Laboratory Programs:

1. Train a classical Support Vector Machine (SVM) on a linearly inseparable dataset (e.g., Iris dataset) and log the baseline accuracy and execution time.
2. Build a classical Convolutional Neural Network (CNN) for image classification (e.g., MNIST dataset digits) to establish a classical processing baseline.
3. Map classical binary data into quantum states using Basis Encoding, Angle Encoding, and Amplitude Encoding techniques.
4. Construct a quantumfeature map (e.g., ZZFeatureMap) to project classical data into a higher-dimensional quantum Hilbert space.
5. Implement a Quantum Support Vector Machine (QSVM) using the Quantum Kernel Trick to classify a linearly inseparable dataset.
6. Design a Parameterized Quantum Circuit (PQC) Ansatz and observe how changing the classical parameter inputs alters the measurement probability distribution.
7. Implement a hybrid optimization loop using a classical optimizer (e.g., Gradient Descent) to iteratively update the parameters of a quantum circuit.
8. Implement a Quantum Convolutional Neural Network (QCNN) layer for basic image edge detection or feature extraction.
9. Simulate the theoretical setup of a Quantum Generative Adversarial Network (QGAN) for a simple data generation task.
10. Run a classical ML model versus a hybrid Quantum Machine Learning (QML) model on a real-world dataset (e.g., weather forecasting) and critically compare performance metrics**.**

Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- **Software-Centric Delivery:** The theoretical explanation of algorithms (like Grover's) is immediately followed by hands-on construction within the QCC, allowing students to visualize amplitude amplification dynamically rather than purely mathematically.
- **AI-Assisted Synthesis:** Leveraging the QCC Utility Mode to abstract complex oracle generation, allowing students to focus on algorithmic inputs and results rather than getting bogged down in manual gate alignment for large-scale algorithms.

Assessment Structure:
The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.

- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal EvaluationCIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
11.		
12.		

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
17.		
18.		
19.		
20.	(Add rows if required)	

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
13.		
14.		
15.		
16.	(Add rows if required)	

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Solid State Physics			
Course Code	1MQT107A	Scheme	2026
Type of Course	**PEC**	Semester	I
Teaching Hours/Week (L:T:P)	2: 0: 0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	60 Hours (L:28, T:0, P:0, TW+SL:32)	SEE Marks	50
Credits	**2 Credit**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. Understand the fundamental differences between crystalline and amorphous solid phases of matter.
2. Formulate and visualize crystal structures, Bravais lattices, and Brillouin zones.
3. Analyze the theory of phonons and vibrational modes within 1D lattices.
4. Apply the Drude model, Bloch theorem, and Band Theory to model electron behavior in solids.

Module-1

Introduction to Solid Phase and Crystal Structure: Introduction to the solid phase of matter. Typical properties of solids. Microscopic structure of solids: crystalline vs. amorphous. Crystal structure fundamentals: Bravais lattices in two and three dimensions. Unit cells, primitive cells, and the Wigner-Seitz unit cell.

Number of Hours: 06

Module-2

Reciprocal Lattice and k-Space: Concept of Real and k-spaces (reciprocal space). Derivation of reciprocal lattice vectors. Brillouin zones. Diffraction of waves by crystals: Bragg's law and von Laue formulation. Equivalence of Bragg and Laue formulations.

Number of Hours: 05

Module-3

Phonons and Vibrational Modes: Vibrations of crystals with monatomic basis. 1D lattice and phonon dispersion. Lattice with two atoms per primitive basis (diatomic lattice). Quantization of elastic waves: Phonons. Optical and acoustic phonon modes. Phonon momentum and inelastic scattering by phonons. Thermal properties: Einstein and Debye models of heat capacity.

Number of Hours: 06

Module-4

Electrons in Solids: Free electron gas: The Drude model. Electrical and thermal conductivity. Quantum theory of free electrons: Fermi-Dirac distribution, density of states in different dimensions (1D, 2D, 3D), and Fermi energy. Electrons in a periodic potential: Bloch's theorem.

Number of Hours: 06

Module-5

Band Theory and Material Classifications: The Kronig-Penney model. Origin of energy bands. Effective mass of an electron. Classification of materials based on band gaps: Conductors, Insulators, and Semiconductors. Intrinsic and extrinsic semiconductors. **Application Context:** How these solid-state properties influence the design of superconducting circuits and semiconductor quantum dots.

Number of Hours: 05

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. **Kittel, C., *Introduction to Solid State Physics*, 8th Edition, Wiley India Edition (2019).**
2. **Ashcroft, N. W., and Mermin, N. D., *Solid State Physics*, Cengage Learning (2003).**
3. **Marder, M. P., *Condensed Matter Physics*, 2nd Edition, John Wiley and Sons (2010).**

Web links and Video Lectures (e-Resources):

https://www.youtube.com/watch?v=IKJAJdDEqhM&t=657s
https://www.youtube.com/watch?v=r2NMWEsNcTs

https://www.youtube.com/watch?v=vy-qStGSy0g

https://www.youtube.com/watch?v=iW-k3Hphbh4&list=PLwdnzlV3ogoUfI5wrKOiYVTThdFAriFji

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Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- ICT-Enabled Teaching
- Simulation and Virtual Labs
- Think-Pair-Share

Assessment Structure:
The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the CIE, a student must score at least 40% of 50 marks, i.e., 20 marks.
- To pass the SEE, a student must score at least 35% of 50 marks, i.e., 18 marks.
- Notwithstanding the above, a student is considered to have passed the course, provided the combined total of CIE and SEE is at least 40 out of 100 marks.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal EvaluationCIE [25+25=50 marks]
A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.
In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.
It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
13.	Case Study Presentation	10
14.	Tool/Software Exploration	15

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
21.		
22.		
23.		
24.	(Add rows if required)	

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
5.		
6.		

7.		
8.	(Add rows if required)	

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Optical Communication			
Course Code	1MQT107B	Scheme	2026
Type of Course	**PEC**	Semester	I
Teaching Hours/Week (L:T:P)	2: 0: 0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	60 Hours (L:28, T:0, P:0, TW+SL:32)	SEE Marks	50
Credits	**2 Credit**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. Understand the core electromagnetic theory governing light propagation in free space and fibers.
2. Analyze the components of an optical link, including lasers, LEDs, and photodetectors.
3. Model and evaluate digital modulation formats (ASK, PSK, QAM) for optical data transmission.
4. Calculate power budgets, attenuation, and dispersion constraints within optical fiber networks.

Module-1

Overview and Electromagnetic Foundations: Overview of optical communications: free space communications versus fiber-based communications. Optical spectral bands (O, C, and L bands), ITU grid. Electromagnetic theory basics: Wave equations, reflection and transmission of waves. Divergence of a Gaussian beam in an isotropic medium.

Number of Hours: 05

Module-2

Optical Fibers and Multiplexing: Propagation in optical fibers. Step-index and graded-index fibers. Single-mode and multi-mode fibers. Signal degradation: Attenuation (scattering, absorption) and Dispersion (modal, chromatic, polarization-mode). Multiplexing techniques: Polarization, wavelength (WDM), and time division multiplexing. WDM components: multiplexer/demultiplexer, add/drop multiplexers, directional couplers.

Number of Hours: 06

Module-3

Optical Transmitter Components and Lasers: Physics of optical emission. Light-Emitting Diodes (LEDs): principles, structures, and quantum efficiency. Laser Diodes: Stimulated emission, population inversion, and optical feedback. Laser rate equations. Linewidth and coherence of a laser. Optical modulation techniques: Direct modulation versus external (indirect) modulation.

Number of Hours: 06

Module-4

Digital Modulation Formats: Principles of digital signaling over optical links. Modulation formats: Amplitude-Shift Keying (ASK), Phase-Shift Keying (PSK), and Quadrature Amplitude Modulation (QAM). Constellation diagrams. Simulation models of modulation. Optical implementation of complex modulation schemes using Mach-Zehnder Modulators.

Number of Hours: 05

Module-5

Optical Receivers and System Noise: Principles of photo-detection. Photodetector types: PIN photodiodes and Avalanche Photodiodes (APDs). Performance characteristics (responsivity, quantum efficiency). Noise in photodetection: Thermal noise, dark current noise, and shot noise. Noise Equivalent Power (NEP). Receiver front-end design: The transimpedance amplifier. Signal-to-Noise Ratio (SNR) and Bit Error Rate (BER) calculations.

Number of Hours: 06

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. **Keiser, G., *Optical Fiber Communications*, 5th Edition, McGraw-Hill (2013).**
2. **Senior, J. M., *Optical Fiber Communications: Principles and Practice*, 3rd Edition, Prentice Hall (2009).**
3. **Agrawal, G. P., *Fiber-Optic Communication Systems*, 4th Edition, Wiley (2010).**

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