PANIMALAR ENGINEERING COLLEGE

(An Autonomous Institution, Affiliated to Anna University, Chennai)
Bangalore Trunk Road, Varadharajapuram,
Poonamallee, Chennai – 600123

Minor Degree
QUANTUM TECHNOLOGIES
Curriculum & Syllabus

DEPARTMENT OF
COMPUTER SCIENCE AND BUSINESS SYSTEMS

REGULATION 2023

PANIMALAR ENGINEERING COLLEGE

Department of Computer Science and Business Systems

MINOR DEGREE COURSE
on
QUANTUM TECHNOLOGIES

S. No	COURSE CODE	COURSE TITLE	Category	L/T/P	Contact Hours	Credit	Ext / Int Weightage
1.	23CB4001	Survey on Quantum Technologies and its Applications	PE	3/0/0	3	3	60/40
2.	23CB4002	Foundations of Quantum Technologies	PE	3/0/0	3	3	60/40
3.	23CB4003	Numerical Methods and Computational Physics	PE	2/0/2	4	3	60/40
4.	23CB4004	Introduction to Quantum Computation	PE	3/0/0	3	3	60/40
5.	23CB4005	Introduction to Quantum Materials	PE	3/0/0	3	3	60/40
6.	23CB4006	Engineering Foundations of Quantum Technologies	PE	3/0/0	3	3	60/40
7.	23CB4007	Solid State Physics for Quantum Technologies	PE	3/0/0	3	3	60/40
8.	23CB4008	Quantum Optics	PE	3/0/0	3	3	60/40

23CB4001	SURVEY ON QUANTUM TECHNOLOGIES AND ITS APPLICATIONS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

- Explain the fundamental principles of quantum mechanics (superposition, entanglement, tunneling) and contrast them with classical physics.
- Analyze the working principles of diverse qubit implementations (superconducting, trapped ions, photonic, etc.) and evaluate their suitability for quantum computation.
- Demonstrate how quantum sensing leverages quantum properties (e.g., entanglement, coherence) for high-precision applications.
- Compare quantum communication protocols with classical methods, and assess the challenges/advances in fiber-based and satellite-based quantum networks.

UNIT I INTRODUCTION TO QUANTUM TECHNOLOGIES 9

Motivation for Quantum Technologies – Overview: Quantum Computing, Quantum Sensing, Quantum Communication, and Quantum Simulation - Feynman's idea of a quantum simulator.

UNIT II FOUNDATIONS OF QUANTUM PHYSICS 9

Quantum States, Wavefunctions, and Probabilistic Interpretation - Observables, Hermitian Operators, Expectation Values - Heisenberg Uncertainty Principle - Schrödinger Equation and Time Evolution - Key Quantum Phenomena: Superposition, Tunneling, Entanglement. No-Cloning Theorem - Distinction from Classical Physics

UNIT III QUANTUM COMPUTATION 9

Basics of Qubits vs Classical Bits - DiVincenzo Criteria for Qubit Realization - Quantum Gates and circuits - Physical Implementations of Qubits - Solid-State (Superconducting, Semiconducting, Topological) - Atomic & Photonic (Trapped Ions, Rydberg Atoms, Neutral Atoms, Photonics) - NMR & NV Centers - Quantum Algorithms (Shor's Algorithm, RSA) - Quantum Advantage and Error - Correction

UNIT IV QUANTUM SENSING AND METROLOGY 9

Principles of Quantum Sensing - Single & Entangled Photon Generation/Detection - Applications: Gravimetry, Atomic Clocks, Magnetometry - State-of-the-Art in Quantum Sensing Technologies.

UNIT V QUANTUM COMMUNICATION 9

Basics of Classical Communication & Shannon Entropy - Quantum Communication Fundamentals: Security & Eavesdropping Implementations: Fiber-based Quantum Networks, Free-Space & Satellite-based Quantum Communication - Recent Achievements and Future Prospects.

TOTAL PERIODS: 45 HOURS

COURSE OUTCOMES:

Upon completing this course, students will be able to:

CO1: Explain the fundamental physical principles behind the realization of qubits for quantum computation.

CO2: Compare and contrast different hardware implementations of qubits (e.g., superconducting, trapped ions, photonic, and solid-state systems).

CO3: Describe the core concepts of quantum sensing, including precision measurement techniques exploiting quantum properties.

CO4: Analyze real-world applications of quantum sensing in gravimetry, magnetometry, atomic clocks, and other advanced metrology systems.

CO5 Understand the principles of secure quantum communication, including protocols for encryption and eavesdropping detection.

CO6: Evaluate the challenges and implementations of quantum communication in both fiber-based and free-space (satellite) architectures.

REFERENCE BOOKS:

1. Quantum Information Science – Manenti R., Motta M., 1st Edition, Oxford University Press (2023)

2. Quantum computation and quantum information – Nielsen M. A., and Chuang I. L., 10th Anniversary edition, Cambridge University Press (2010)

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

4. An Introduction to Quantum Computing, Phillip Kaye, Raymond Laflamme, and Michele Mosca, Oxford University Press (2006)

5. Quantum computing explained, David McMahon, Wiley (2008)

WEB LINKS:

1. https://archive.nptel.ac.in/courses/106/106/106106232/
2. https://learning.quantum.ibm.com/tutorial/explore-gates-and-circuits-with-the-quantum-composer
3. https://learning.quantum.ibm.com/

CO- PO MAPPING

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO1 0	PO1 1
CO1	3	2	2	-	-	-	-	-	-	-	-
CO2	3	2	2	-	-	-	-	-	-	-	-
CO3	3	3	2	-	-	-	-	-	-	-	-
CO4	3	3	3	-	-	-	-	-	-	-	-
CO5	3	3	3	-	-	-	-	-	-	-	-
CO6	3	2	2	2	1						

Internal Assessment				**End Semester Examinations**
Assessment I (100 Marks)		**Assessment II (100 Marks)**		
Individual Assignment / Case Study / Seminar / Mini Project	**Written Test**	**Individual Assignment / Case Study / Seminar / Mini Project**	**Written Test**	**Written Examinations**
40	60	40	60	100
40%				**60 %**

23CB4002	FOUNDATIONS OF QUANTUM TECHNOLOGIES	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

- To understand the basic concepts of quantum mechanics.
- To acquire knowledge of various quantum operators and their applications in quantum computation.
- To infer knowledge on the deeper principle of quantum computing.
- To get Knowledge regarding the relevance of thermodynamics in quantum computation.
- To comprehend the fundamentals of Entropy in relating quantum information.
- To illustrate Finite automata in solving computational problems.

UNIT I QUANTUM MECHANICS 9

Postulates of Quantum mechanics – Free electron Theory – Drawbacks of Classical Theory – Planck's Quantum Hypothesis – Atomic spectra – de Broglie 's wave particle duality - Wave function (Ψ) – Quantization of energy (Eigen values) – Heisenberg Uncertainty Principle – Eigen value and Eigen function- Schrodinger's equations – Applications.

UNIT II QUANTUM OPERATORS 9

Complex numbers – Vectors and Coordinate systems – Matrices - Inner and outer product –State vectors – Hilbert space – Dirac bra -Ket notations – Hermitian operator – Unitary Transformation - Quantum states – Density operators – Bits and Qubits – Single and multiple Qubit systems – Bloch sphere representation.

UNIT III FUNDAMENTALS OF QUANTUM COMPUTATION 9

Spin and angular momentum – Spin half particles – Boson and fermions - WKB approximation – EPR paradox – Bell states –No cloning theorem – Quantum correlation- Pair and mixed states – Superposition and entanglement- Quantum computing with photons.

UNIT IV STATISTICAL PHYSICS IN COMPUTATION 9

Quick review of first and second laws of thermodynamics - Thermal Equilibrium and Gibbs principle- Applying Gibbs principle to Classical and Quantum harmonic oscillators- Bosons and Fermions and Quantum statistics – Fermi-Dirac and Bose-Einstein distributions- Quantifying information in terms of Shannon entropy- Quantifying information in terms of Shannon entropy

UNIT V QUANTUM INFORMATION SCIENCE 9

Finite automata-Simpler Notations-Properties of Recursive enumerable language-Digital communication and information- Qualitative ideas of a Turing machine- Types of Turing machines- Algorithm analysis-Time and Space complexity – Quantum complexity classes.

TOTAL PERIODS: 45 HOURS

COURSE OUTCOMES:

Upon successful completion of the course, the students will be able to:

CO1: Understand the basic concepts of quantum mechanics.

CO2: Acquire knowledge of various quantum operators and their applications in quantum computation.

CO3: Infer knowledge on the deeper principle of quantum computing.

CO4: Get Knowledge regarding the relevance of thermodynamics in quantum computation.

CO5: Comprehend the fundamentals of Entropy in relating quantum information.

CO6: Illustrate Finite automata in solving computational problems.

TEXT BOOKS

1. Introduction to Quantum Mechanics, Griffiths D. J., 3rd Edition, Cambridge University Press (2024)

2. Introduction to Electrodynamics, Griffiths D. J., 4th edition, Cambridge University Press (2020)

3. Principles of Quantum Mechanics, Shankar, R., 2nd edition, Springer (2014)

4. Quantum Information Science – Manenti R., Motta M., 1st Edition, Oxford University Press (2023)

5. Quantum computation and quantum information – Nielsen M. A., and Chuang I. L., 10th Anniversary edition, Cambridge University Press (2010)

REFERENCES BOOKS

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

2. Information Theory, Robert B. Ash, Dover Publications (2003)

3. Introduction to the Theory of Computation, Michael Sipser, 3rd edition, Cengage India Pvt. Ltd. (2014)

4. Statistical Mechanics, Pathria R. K., Paul D. Beale, 4th edition, Academic Press, (2021)

CO- PO MAPPING

	PO 1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO1 0	PO1 1
CO 1	3	3	1	-	-	-	-	-	-	-	-
CO 2	3	3	1	-	-	-	-	-	-	-	1
CO 3	3	3	2	-	-	--	-	-	-	-	1
CO 4	3	3	2	1	1	-	-	-	-	-	2
CO 5	3	3	2	1	1	-	-	-	-	-	2
CO 6	3	3	2	2	2	-	-	-	-	-	2

Internal Assessment				**End Semester Examinations**
Assessment I (100 Marks)		**Assessment II (100 Marks)**		
Individual Assignment / Case Study / Seminar / Mini Project	**Written Test**	**Individual Assignment / Case Study / Seminar / Mini Project**	**Written Test**	**Written Examinations**
40	60	40	60	100
40%				**60 %**

23CB4003	NUMERICAL METHODS AND COMPUTATIONAL PHYSICS	L	T	P	C
		2	0	1	3

COURSE OBJECTIVES:

- To introduce students to fundamental programming concepts including data structures
- To acquaint the knowledge of various techniques and methods of solving ordinary differential equations..
- To find the numerical solution of Eigen value problems by Numerical techniques and to perform matrix decomposition.
- To provide the necessary basic concepts of probability and statistics by using numerical methods.
- Experience in simulating physical systems in quantum mechanics and electromagnetism using modern programming tool

UNIT I PROGRAMMING FOUNDATIONS AND ALGORITHMIC TECHNIQUES 7

Basics of programming - Data structures, classes, Object-oriented programming - Data storage and retrieval, Memory allocation - Scientific plotting, documentation of codes - Simple algorithms and benchmarking run time, Sorting , Searching , Arithmetic algorithms like GCD, Prime factorisation

UNIT II NUMERICAL INTEGRATION AND DIFFERENTIAL EQUATIONS 5

Linear 2nd Order ODEs with constant coefficients - Linear 2nd order ODEs with variable coefficients - Boundary value problems: Poisson equation, Laplace equation, Wave equation and Diffusion Equation.

UNIT III NUMERICAL TECHNIQUES IN LINEAR ALGEBRA 5

Matrix inverse - Eigenvalue problem - Diagonalisation of matrices - Singular value decomposition.

UNIT IV NUMERICAL TECHNIQUES IN PROBABILITY AND STATISTICS 5

(Pseudo) Random number generation - Computing statistical moments for data samples - Least Squares fitting - Hypothesis Testing - Monte Carlo sampling.

UNIT V COMPUTATIONAL APPLICATIONS IN QUANTUM MECHANICS AND ELECTROMAGNETISM 8

Applications to Quantum Mechanics - Eigen energies of coupled two level systems - Eigen energies of two-level system coupled to oscillator (Jaynes-Cummings Model) - Driven two-level system – Rabi Problem ○ Driven damped oscillator — coherent states - Applications to EM theory (e.g. magnetic field simulation)- Electrostatic charge distributions- Magnetostatic current distributions - Finite Element techniques for electromagnetic simulations

TOTAL PERIODS: 30 HOURS

LIST OF EXPERIMENTS

1. Implement classes and objects to represent particles with mass, charge, spin.
2. Implement sorting and searching algorithms and compare run-times.
3. Prime factorization and GCD using recursive and iterative methods.
4. Solving second order ODE.
5. Evaluating line integral by Simpson’s 1/3 method.
6. Evaluating line integral by Trapezoidal method.
7. Find inverse of matrix.
8. Find the largest Eigen value by Power method.
9. Simulation: Random number generation
10. Monte Carlo method

TOTAL PERIODS: 15 HOURS

TEXT BOOKS

1. Grewal, B.S., and Grewal, J.S., "Numerical Methods in Engineering and Science", Khanna Publishers, 10th Edition, New Delhi, 2015.
2. Faires J.D. and Burden R, Numerical Methods, Brooks/Cole (Thomson Publications), New Delhi, 2002.
3. Robert Sedgewick, Kevin Wayne "Algorithms, “4th Edition, Pearson, 2011.
4. Excellent for sorting, searching, and runtime analysis.
5. Mark Lutz "Learning Python", O'Reilly Media, 5th Edition, 2013.
6. Zelle, John M. "Python Programming: An Introduction to Computer Science", Franklin, Beedle & Associates Inc., 3rd Edition, 2016.

REFERENCES

1. Computational Physics, Nicholas Giordano, Hisao Nakanishi, 2nd edition, PearsonAddison Wesley (2005)
2. Kandasamy, P., Thilagavathy ,K.,andGunavathy,S., „Numerical Methods‟, Chand and Co.,2007

COURSE OUTCOMES:

Upon completion of the course, the students will be able to

CO1: Develop structured programs using basic data structures, classes, and algorithms, and evaluate their performance through code documentation and benchmarking techniques.

CO2: Develop, visualize, and benchmark simple algorithms for sorting, searching, and arithmetic operations using appropriate programming constructs.

CO3: Solve the partial and ordinary differential equations with initial and boudary conditions by using certain techniques with engineering applications.

CO4: Apply the numerical techniques to perform matrix decomposition, inverse of matrix and Eigen value problems

CO5: Apply the numerical methods in probability and statistics for engineering problems

CO6: Implement numerical simulations of quantum mechanical and electromagnetic systems using Python/Julia and interpret results related to eigenvalues, driven systems, and EM field distributions.

CO- PO MAPPING

	PO 1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO1 0	PO1 1
CO 1	3	2	2	–	2	–	–	–	–	1	–
CO 2	3	3	2	2	2	–	–	–	–	1	–
CO 3	3	3	3	2	1	–	–	–	–	–	–
CO 4	3	2	3	2	2	–	–	–	–	–	–
CO 5	3	2	3	2	1	–	–	–	–	–	–
CO 6	3	2	3	3	3	–	1	–	–	–	1

Assessment (40% weightage) (Theory Component)		**Assessment** (60% weightage) (Laboratory Component)		**End Semester Examination**
Individual Assignment / Case Study / Seminar / Mini Project	**Written Test**	**Evaluation of Laboratory Observation, Record**	**Test**	**Written Examination**
40	**60**	**75**	**25**	
100				**100**
50 %				**50 %**

23CB4004	INTRODUCTION TO QUANTUM COMPUTATION	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

- Introduce the conceptual foundation of quantum computation by contrasting classical bits with qubits and exploring physical implementations of quantum systems
- Familiarize students with quantum logic gates and circuits, including the Solovay–Kitaev theorem and universal gate sets
- Explore fundamental quantum algorithms such as Deutsch–Jozsa, Simon's, Grover's, and Shor's algorithms, and highlight their computational advantages
- Introduce quantum complexity theory and its key classes such as BQP, QMA, and others, along with classical counterparts
- Discuss advanced quantum algorithms like Variational Quantum Eigensolver (VQE), HHL, and QAOA, focusing on their practical implications.
- Provide foundational knowledge of quantum error correction, including fault- tolerant computing, and survey the current landscape of quantum hardware and future directions.

UNIT I: QUBITS AND QUANTUM SYSTEMS ***9***

Classical bits vs Qubits -Spin-half systems and photon polarizations , Trapped atoms and ions , Artificial atoms using circuits- Semiconducting quantum dots , Introduction to single and two qubit gates , Solovay–Kitaev Theorem , Basic physical realizations of qubits

UNIT II: QUANTUM ENTANGLEMENT AND CORRELATIONS ***9***

Quantum correlations and entanglement- Bell's theorems and non-locality - Review of classical computation , Turing machines , Time and space complexity (P, NP, PSPACE) - Introduction to reversible computation -Basics of universal quantum logic gates and circuits

UNIT III: CORE QUANTUM ALGORITHMS **9**

Quantum Algorithms - Deutsch algorithm ,Deutsch–Jozsa algorithm ,Bernstein–Vazirani algorithm ,Simon's algorithm - Database search with Grover's algorithm - Quantum Fourier Transform -Prime factorization and Shor's algorithm.

UNIT IV: QUANTUM COMPLEXITY AND ADVANCED ALGORITHMS ***9***

Quantum complexity classes: Q, EQP, BQP, BPP, QMA - Introduction to Variational Quantum Eigensolver (VQE) - HHL algorithm - Quantum Approximate Optimization Algorithm (QAOA) - Quantum decoherence and noise (brief context for real-world quantum computing)

UNIT V: ERROR CORRECTION AND INDUSTRY PERSPECTIVE ***9***

Basics of quantum error correction - Fault-tolerant computing - Simple error correcting codes - Survey of current status: NISQ era processors , Quantum advantage claims - Industry roadmaps and future perspectives

TOTAL PERIODS: 45 HOURS

TEXT BOOKS

1. Quantum Information Science – Manenti R., Motta M., 1st Edition, Oxford University Press (2023)
2. Quantum computation and quantum information – Nielsen M. A., and ChuangL., 10th Anniversary edition, Cambridge University Press (2010)
3. A Pathak, Elements of Quantum Computation and Quantum Communication, Boca Raton, CRC Press (2015)

REFERENCES

1. Quantum error correction and Fault tolerant computing, Frank Gaitan, 1st edition, CRC Press (2008)
2. Quantum computing explained, David McMahon, Wiley (2008)
3. Introduction to Quantum Computing: From a lay person to a programmer in
4. 30 steps, Hui Yung Wong, 1st edition, Springer-Nature Switzerland AG (2022:

COURSE OUTCOMES:

Upon completion of the course, the students will be able to

CO1: Review and apply basic postulates of quantum mechanics.

CO2: Understand the theoretical basis of qubits and their physical realizations.

CO3: Work with density operators and describe the time evolution of mixed quantum states.

CO4: Understand and analyze quantum gates and circuits.

CO5: Apply core quantum algorithms (e.g., Deutsch, Shor, Grover) to problem solving.

CO6: Explain the need for and basics of quantum error correction techniques.

CO- PO MAPPING

	PO 1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO1 0	PO1 1
CO 1	3	2	2	1	–	–	–	–	–	–	–
CO 2	3	3	3	2	1	–	–	–	–	–	–
CO 3	2	3	3	2	–	–	–	–	–	–	–
CO 4	3	3	3	3	2	–	–	–	–	–	–
CO 5	2	2	3	3	3	–	–	–	–	–	–
CO 6	2	2	2	2	2	–	–	–	–	–	–

Internal Assessment				End Semester Examinations
Assessment I (100 Marks)		Assessment II (100 Marks)		
Individual Assignment / Case Study / Seminar / Mini Project	Written Test	Individual Assignment / Case Study / Seminar / Mini Project	Written Test	Written Examinations
40	60	40	60	100
40%				60 %

23CB4005	INTRODUCTION TO QUANTUM MATERIALS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

- Understand the basic idea of quantum materials by band theory of solids
- Describe the principles and basics of magnetism and the magnetic measurements
- Explain the basics properties of superconductivity in engineering application
- Analyze about new 2D materials like graphene, TMDCs and topology and topological phases of matter to enhance the knowledge and utilizing it in different field of application
- Apply the different material growth techniques to develop the different materials which are useful in engineering field

UNIT I FUNDAMENTALS OF BAND THEORY 9

Metals, Semiconductors and Insulators - Band structure of solids - Quantum free electron theory - Band theory of solids or Zone theory - Origin of Energy band formation in Solids - Survey of semiconducting devices for quantum technologies - masers, quantum computers, and various quantum sensors – Magnetometers, Quantum Biosensors, Quantum Imaging.

UNIT II MAGNETISM 9

Magnetism in materials - Para, ferro magnetism basics – Ferromagnetic domain theory –M versus H behavior – hard and soft magnetic materials – Magnetic principles in computer data storage - Magnetic measurements - Hall effect - Magneto resistance experiment - Faraday and Kerr effects in ferromagnetism

UNIT III SUPER CONDUCTIVITY 9

Zero resistance and Meissner effect - critical field and critical current density – BCS theory - Ginzburg Landau - Josephson Effect – AC and DC Josephson effects - superconducting quantum interference devices (SQUIDs) (theoretical description of DC- and RF-SQUIDs, SQUID design, SQUID readout, SQUID applications) - SQUID based low-and high-frequency amplifiers - Superconducting Quantum Bits (Cooper pair box, flux qubit, phase qubit, transmon qubit, etc.)

UNIT IV **2D MATERIALS** **9**

Graphene and its properties – single and few layers - Transition Metal Dichalcogenides – Electronic and Optical Properties - Topological Phases of matter - Basics of Topology - Geometric phases - Berry Phase - Aharonov Bohm effect - Topological phases of matter - quantum condensate - exotic states of matter.

UNIT V **MATERIAL GROWTH TECHNIQUES** **9**

Molecular beam epitaxy - Chemical vapor deposition, MOVPE - Pulsed laser deposition- Crystal growth techniques - basics of crystal growth - conditions for growing crystal - Bridgmann method - Czochralski method.

TOTAL PERIODS: 45 HOURS

COURSE OUTCOMES:

Upon completing this course, students will be able to

CO1: Understand the basic idea of quantum materials by band theory of solids

CO2: Comprehend the principles and basics of magnetism and the magnetic measurements

CO3: Apply the basics properties of superconductivity in engineering application

CO4: Analyze about new 2D materials like graphene,

CO5: TMDCs and topology and topological phases of matter to enhance the knowledge and utilizing it in different field of application

CO6: Apply the different material growth techniques to develop the different materials

REFERENCE BOOKS:

1. Condensed Matter Physics, M P Marder, 2nd Edition, John Wiley and Sons, 2010
2. Introduction to Superconductivity, Michael Tinkham, standard ed., Medtech (2017)
3. Quantum computation and quantum information – Nielsen M. A., and Chuang I. L., 10th Anniversary edition, Cambridge University Press (2010)
4. Elements of Quantum Computation and Quantum Communication, A. Pathak, Boca Raton, CRC Press (2015)
5. An Introduction to Quantum Computing, Phillip Kaye, Raymond Laflamme, and Michele Mosca, Oxford University Press (2006)

CO- PO MAPPING

	PO 1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO1 0	PO1 1
CO1	3	2	2	-	-	-	-	-	-	-	-
CO2	3	2	2	-	-	-	-	-	-	-	-
CO3	3	3	2	-	-	-	-	-	-	-	-
CO4	3	3	3	-	-	-	-	-	-	-	-
CO5	3	3	3	-	-	-	-	-	-	-	-
CO6	3	2	2	2	1						

Internal Assessment				**End Semester Examinations**
Assessment I (100 Marks)		**Assessment II (100 Marks)**		
Individual Assignment / Case Study / Seminar / Mini Project	**Written Test**	**Individual Assignment / Case Study / Seminar / Mini Project**	**Written Test**	**Written Examinations**
40	60	40	60	100
40%				**60 %**

23CB4006	ENGINEERING FOUNDATIONS OF QUANTUM TECHNOLOGIES	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

- To introduce the fundamental principles of computation, models of computation, and complexity theory that underpin computer science.
- To provide foundational knowledge of classical and modern cryptographic techniques, including number theory and quantum-resistant approaches.
- To understand the behavior of RLC circuits and transmission line fundamentals, resonators for efficient signal transmission.
- To study the characteristics of signal and noise to design systems.
- To learn analog and digital modulation techniques and coding.

UNIT I ELECTRICAL NETWORKS: 7

Introduction to RLC Circuits-Impedance of RLC Circuits-Resonance in RLC Circuits-Quality Factor (Q Factor)- Transmission Line Basics-Telegrapher equations, wave impedance, impedance matching, transmission line resonators.

UNIT I – FOUNDATIONS OF COMPUTATION AND COMPLEXITY 11

Basics of Computer Architecture – Arithmetic Logic Unit (ALU) and Memory systems. Abstract Models of Computation – Finite State Machines (FSM), Turing Machines. Overview of Language Hierarchy – Regular, Context-Free, Turing-Decidable, and Turing-Recognizable languages. Introduction to Complexity Theory – Time and Space Complexity, P vs NP Problem, and the concept of NP-Completeness.

UNIT III NOISE AND SIGNALS 9

Characterising Noise - Types of Noise - Shot Noise - Johnson-Nyquist Noise - Telegraphic noise or flicker or 1/f noise - Signal conditioning and noise mitigation - Amplification and Added Noise - Linear Amplifier theory - Signal-Noise Ratio, Added Noise, Noise Figure of amplification - Dynamic Range - Noise temperature - Quantum limits on noise in linear amplifiers.

UNIT IV ANALOG AND DIGITAL COMMUNICATION 9

Introduction to Modulation - Quadrature amplitude modulation - Heterodyne and Homodyne demodulation. Information entropy - Noiseless channel encoding - Shannon's source coding theorem, Noisy channel encoding - Shannon's Channel Coding Theorem

UNIT V – FUNDAMENTALS OF CRYPTOGRAPHY **9**

Basics of Number Theory – Prime Numbers, Modular Arithmetic, Euler's Theorem, and Greatest Common Divisor (GCD).Random Number Generation – True and Pseudo-Random Generators and their role in cryptographic systems. Introduction to Cryptographic Protocols – One-Time Pad, Private Key and Public Key Cryptography, Symmetric and Asymmetric encryption. Practical Cryptography – RSA Algorithm and Diffie-Hellman Key Exchange. Post- quantum Cryptography (PQC) – Need for quantum- resistant cryptosystems, overview of lattice- based approaches and quantum threats.

TOTAL PERIODS: 45 HOURS

TEXT BOOKS

1. Art of Electronics, Paul Horowitz and Winfield Hill, 3rd edition, Cambridge University Press (2015)
2. Digital Design, Morris Mano, Michael D. Cilletti, 6th edition, Pearson Education (2018)
3. Microwave Engineering, David Pozar, 4 th edition, Wiley (2013)
4. Information Theory, Robert B. Ash, Dover Publications (2003)

REFERENCES

1 Introduction to the Theory of Computation, Michael Sipser, 3rd edition, Cengage India Pvt. Ltd. (2014)

2. Protecting Information – From Classical error correction to quantum cryptography, Susan Loepp and William K. Wootters, Cambridge University Press (2006)

COURSE OUTCOMES:

Upon completion of the course, the students will be able to

Upon completion of the course, the students will be able to:

CO1: Identify RLC circuits for desired resonance and apply impedance matching techniques to optimize signal transmission.

CO2: Analyse signal and noise from RF and Microwave Engineering to design systems.

CO3: Discuss analog and digital modulation techniques and coding.

CO4: Explain and analyse models of computation, formal language hierarchies, and complexity classes, including FSMs, Turing Machines, and NP-completeness.

CO5: Apply number theory and random number generation techniques to understand and compare classical and post-quantum cryptographic protocols such as RSA and Diffie-Hellman.

CO- PO MAPPING

	PO 1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO1 0	PO1 1
CO1	3	2	2	2	2	–	–	–	–	–	–
CO2	3	3	3	2	2	–	–	–	–	–	–
CO3	3	2	2	2	2	–	–	–	–	–	–
CO4	3	3	3	3	2	–	–	–	–	1	–
CO5	3	2	3	3	3	–	–	–	–	1	–

Internal Assessment				**End Semester Examinations**
Assessment I (100 Marks)		**Assessment II (100 Marks)**		
Individual Assignment / Case Study / Seminar / Mini Project	**Written Test**	**Individual Assignment / Case Study / Seminar / Mini Project**	**Written Test**	**Written Examinations**
40	60	40	60	100
40%				**60 %**

23CB4007	SOLID STATE PHYSICS FOR QUANTUM TECHNOLOGIES	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

By the end of this course, students will be able to:

- To provide a solid foundation in the structure of crystalline solids and their physical properties.
- To introduce the theoretical models and mechanisms that governs the electrical, thermal, and magnetic behavior of materials.
- To help students understand and apply classical and quantum models**,** such as Free Electron Model, Band Theory, Phonons, and Bloch's Theorem.
- To expose students to superconductivity and its applications, and highlight the roles of superconducting devices in the technological aspects.
- To foster analytical thinking and problem-solving skills by applying theory to explain physical properties and developing advanced electronic and quantum devices.

UNIT-I STRUCTURE OF SOLIDS AND CHARACTERIZATION 9

Unit cell – Different types of crystal structures - Atomic scattering and structural factors. Characterization tools – X-Ray diffraction (XRD) – Fourier transform and Infrared spectroscopy (FTIR) – Raman Scattering –X-ray Photon spectrpscopy (XPS) – Atomic Force Microscopy (AFM).

UNITII BONDING IN SOLIDS AND THEIR PROPERTIES 9

Bonds- Ionic – Covalent- van der Waals and Repulsive interactions, Lennard Jones potential, Madelung constant Electron theories - The Drude theory of metals – DC & AC electrical conductivity of a metal; Hall effect & magnetoresistance, Density of energy states, Fermi-Dirac statistics distribution, Specific heat of degenerate electron gases.

UNIT III ELECTRON THEORIES AND THE FORMATION OF ENERGY BANDS 9

Classical theory of solids – Quantum Free electron theory **-** Kronig - Penney Model - Electron in a Periodic potential – Brillouin Zones - Bloch Theorem - Band theory – formation of Energy bands, Energy levels and Band gaps - Tight binding approximation- Effective mass – concept of negative mass.

UNIT IV LATTICE VIBRATIONS AND PHONONS **9**

Lattice – Lattice vibrations – Bravais Lattice – Miller Indices – d- Spacing - Laue equations and Bragg's law- Phonons - One dimensional monoatomic and diatomic chains - Normal modes and Phonons- Phonon spectrum - Long wavelength - acoustic phonons and elastic constants vibrational properties- normal modes, acoustic and optical phonons.

UNIT V MAGNETISM AND SUPERCONDUCTIVITY **9**

Magnetic materials - Dia-, Para-, and Ferromagnetism - Langevin's theory of paramagnetism - Weiss Molecular theory - Superconductivity: Phenomenological description – Zero resistance, Meissner effect London Theory - BCS theory- Ginzburg- Landau Theory - Type-I and type-II superconductors, High-Tc superconductivity - Flux quantization – SQUIDs - Josephson's devices.

TOTAL PERIODS: 45 HOURS

COURSE OUTCOMES:

Upon completing this course, students will be able to:

CO1: To understand the crystal structure of solids and methods to characterize crystal structures.

CO2: To explain the bonding mechanisms in solids and compute the related properties.

CO3: To compare the electron theories of solids, and explain the formation of energy bands and band gaps in periodic potentials.

CO4: To analyze lattice vibrations in solids, interpret phonon dispersion, and to relate the thermal properties.

CO5: To describe the different magnetic materials and the phenomena of superconductivity.

CO6: To apply the concept of superconductivity and to develop higher end quantum technologies.

TEXT BOOK

1. Introduction to Solid State Physics, Charles Kittel, Wiley India Edition (2019)
2. Condensed Matter Physics, M P Marder, 2nd Edition, John Wiley and Sons (2010)
3. Introduction to Superconductivity, Michael Tinkham, standard edition, Medtech (2017)

4. Quantum Information Science – Manenti R., Motta M., 1st Edition, Oxford University Press (2023)

REFERENCES BOOK :

1. Quantum computation and quantum information – Nielsen M. A., and Chuang I. L., 10th Anniversary edition, Cambridge University Press (2010)
2. Elements of Quantum Computation and Quantum Communication, A. Pathak, Boca Raton, CRC Press (2015)

computing explained, David McMahon, Wiley (2008)

3. An Introduction to Quantum Computing, Phillip Kaye, Raymond Laflamme, and Michele Mosca, Oxford University Press (2006)

CO - PO MAPPING

4. Quantum

	PO 1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO1 0	PO1 1
CO1	3	2	2	-	-	-	-	-	-	-	-
CO2	3	2	2	-	-	-	-	-	-	-	-
CO3	3	3	2	-	-	-	-	-	-	-	-
CO4	3	3	3	-	-	-	-	-	-	-	-
CO5	3	3	3	-	-	-	-	-	-	-	-
CO6	3	2	2	2	1						

Internal Assessment				**End Semester Examinations**
Assessment I (100 Marks)		**Assessment II (100 Marks)**		
Individual Assignment / Case Study / Seminar / Mini Project	**Written Test**	**Individual Assignment / Case Study / Seminar / Mini Project**	**Written Test**	**Written Examinations**
40	60	40	60	100
40%				**60 %**

23CB4008	QUANTUM OPTICS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

- Understand the quantum nature of electromagnetic field.
- Study the concept of coherence and ordering of operators.
- Analyze phase-space representation in Q-function studies.
- Explore the classical and quantum theory of light-matter interaction.
- Apply quantum system in arriving master equations.

UNIT I QUANTIZATION OF ELECTROMAGNETIC FIELD 9

Classical wave theory – quantum nature of light – Introduction to quantization of the electromagnetic field – concept of photons as discrete energy quanta – Fock states or number states – squeezed states – Hanbury-Brown and Twiss experiments – Photon bunching, Photon anti-bunching – Hong-Ou-Mandel interference

UNIT II THEORY OF OPTICAL COHERENCE 9

Coherence states – light fields with minimum uncertainity – Young's double slit experiment and first order coherence – coherence uncertainity – functions of arbitrary order–Types of ordering – ordering, symmetric ordering and anti-normal ordering of operators – Interferometry

UNIT III PHASE- SPACE REPRESENTATION OF STATES OF LIGHT 9

Introduction to phase-space representations of quantum states – Frequency time domain – Wigner distribution – P Function – non classical states and their applications – Density operator– Husimi Q function.

UNIT IV LIGHT-MATTER INTERACTION 9

Classical Hamiltonian – Classical model of light-matter interaction– Rabi oscillations – optical Bloch equation – Semi-classical model of light-matter interaction–Structured wave guide- Quantum light-matter interaction model–Jayne's cummings model.

UNIT V OPEN QUANTUM SYSTEM 9

Non-radiative rates – Fourier transform – Fermi golden rule – types of steady-states observables – Born-Markov approximation – Markovian reservoir – Born-Markov Lindblad Master equation– resonance fluorescence.

TOTAL PERIODS: 45 HOURS

COURSE OUTCOMES:

Upon completing this course, students will be able to:

CO1: Explain the quantum nature of electromagnetic field.
CO2: Understand the concept of coherence and ordering of operators.
CO3: Apply phase-space representation in Q-function studies.
CO4: Describe oscillations based on classical and semi-classical approach in light- matter interaction.
CO5: Explore quantum approach of matter waves through guiding medium.
CO6: Formulate approximations and master equations in open quantum systems.

TEXT / REFERENCE BOOKS:

1. Quantum Optics by Marlan O. Scully and M. Suhail Zubairy, Cambridge University Press
2. Introduction to Quantum Optics by Gilbert Grynberg, Alain Aspect, Claude Fabre, Cambridge University Press
3. Optical Coherence and Quantum Optics by Leonard Mandel and Emil Wolf, Cambridge University Press
4. Quantum Optics by D.F. Walls and G.J. Milburn, Springer
5. Principles of Quantum Optics by R. Loudon, Oxford University Press

CO- PO MAPPING

	PO 1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO1 0	PO1 1
CO1	3	2	2	1	–	–	–	–	–	–	–
CO2	3	2	2	2	–	–	–	–	–	–	–
CO3	3	3	2	2	–	–	–	–	–	–	–
CO4	3	3	3	2	–	–	–	–	–	–	–
CO5	2	2	2	2	1	–	–	–	–	–	–
CO6	2	2	3	3	2	–	–	–	–	–	–

Internal Assessment				**End Semester Examinations**
Assessment I (100 Marks)		**Assessment II (100 Marks)**		
Individual Assignment / Case Study / Seminar / Mini Project	**Written Test**	**Individual Assignment / Case Study / Seminar / Mini Project**	**Written Test**	**Written Examinations**
40	60	40	60	100
40%				**60 %**