Ravindra College of Engineering for Women: Kurnool
(Autonomous)
(Approved by AICTE | NAAC Accreditation with 'A+' Grade | Accredited by NBA (CSE, ECE) | Affiliated to JNTUA)
Nandikotkur Road, Venkayapalli (V), Kurnool - 518452, Andhra Pradesh

LIST OF MINORS OFFERED TO COMPUTER SCIENCE AND ENGINEERING

COMPUTER SCIENCE AND ENGINEERING

S.No.	Code	Course Name	Contact Hours per week			Credits
			L	T	P	
1	23A05M01	Data Structures and Algorithms	3	-	0	3
2	23A05M02	Introduction to Artificial Intelligence	3	-	0	3
3	23A05M03	Web Technologies	3	-	0	3
4	23A05M04	Introduction to Data Science	3	-	0	3
5	23A05M05	Cloud Computing	3	-	0	3
6	23A05M01P	Data Structures and Algorithms Lab	0	0	3	1.5
7	23A05M03P	Web Technologies Lab	0	0	3	1.5

QUANTUM COMPUTING

S.No.	Code	Course Name	Contact Hours per week			Credits
			L	T	P	
1	23A05M06	Introduction to Quantum Computing	3	-	0	3
2	23A05M07	Mathematical Foundations for Quantum Computing	3	-	0	3
3	23A05M08	Quantum Algorithms	3	-	0	3
4	23A05M09	Quantum Information and Communication	3	-	0	3
5	23A05M10	Quantum Machine Learning (QML)	3	-	0	3
6	23A05M06P	Quantum Algorithms Lab	0	0		1.5
7	23A05M11P	Quantum Programming and Simulation Lab	0	0		1.5

QUANTUM TECHNOLOGIES

S.No.	Code	Course Name	Contact Hours per week			Credits
			L	T	P	
1	23A05M12	Foundations of Quantum Technologies	3	-	0	3
2	23A05M13	Solid State Physics for Quantum Technologies	3	-	0	3
3	23A05M14	Quantum Optics Prerequisites for Quantum Technologies	3	-	0	3
4	23A05M15	Introduction to Quantum Communication	3	-	0	3
5	23A05M16	Introduction to Quantum Sensing	3	-	0	3
6	23A05M15P	Quantum Communication and Sensing Lab	0	0		1.5
7	23A05M17P	Quantum Devices and Materials Lab	0	0		1.5

23A05M01	**DATA STRUCTURES & ALGORITHMS**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

Course Objectives:
The main objectives of the course is to
- provide knowledge on advance data structures frequently used in Computer Science domain
- Develop skills in algorithm design techniques popularly used
- Understand the use of various data structures in the algorithm design

Course Outcomes:
After completion of the course, students will be able to
1. Illustrate the working of the advanced tree data structures and their applications (L2)
2. Understand the Graph data structure, traversals and apply them in various contexts. (L2)
3. Use various data structures in the design of algorithms (L3)
4. Recommend appropriate data structures based on the problem being solved (L5)
5. Analyze algorithms with respect to space and time complexities (L4)

UNIT – I:
Introduction to Algorithm Analysis, Space and Time Complexity analysis, Asymptotic Notations.

AVL Trees – Creation, Insertion, Deletion operations and Applications
B-Trees – Creation, Insertion, Deletion operations and Applications

UNIT – II:
Heap Trees (Priority Queues) – Min and Max Heaps, Operations and Applications
Graphs – Terminology, Representations, Basic Search and Traversals, Connected Components and Biconnected Components, applications
Divide and Conquer: The General Method, Quick Sort, Merge Sort, Strassen‘s matrix multiplication, Convex Hull

UNIT – III:
Greedy Method: General Method, Job Sequencing with deadlines, Knapsack Problem, Minimum cost spanning trees, Single Source Shortest Paths
Dynamic Programming: General Method, All pairs shortest paths, Single Source Shortest Paths– General Weights (Bellman Ford Algorithm), Optimal Binary Search Trees, 0/1 Knapsack, String Editing, Travelling Salesperson problem

UNIT – IV:
Backtracking: General Method, 8-Queens Problem, Sum of Subsets problem, Graph Coloring, 0/1 Knapsack Problem
Branch and Bound: The General Method, 0/1 Knapsack Problem, Travelling Salesperson problem

UNIT – V:
NP Hard and NP Complete Problems: Basic Concepts, Cook‘s theorem
NP Hard Graph Problems: Clique Decision Problem (CDP), Chromatic Number Decision Problem (CNDP), Traveling Salesperson Decision Problem (TSP)
NP Hard Scheduling Problems: Scheduling Identical Processors, Job Shop Scheduling.

Textbooks:

1. Fundamentals of Data Structures in C++, Horowitz, Ellis; Sahni, Sartaj; Mehta, Dinesh, 2nd Edition Universities Press
2. Computer Algorithms in C++, Ellis Horowitz, SartajSahni, SanguthevarRajasekaran, 2nd Edition University Press

Reference Books:

1. Data Structures and program design in C, Robert Kruse, Pearson Education Asia
2. An introduction to Data Structures with applications, Trembley & Sorenson, McGraw Hill
3. The Art of Computer Programming, Vol.1: Fundamental Algorithms, Donald E Knuth, Addison-Wesley, 1997.
4. Data Structures using C & C++: Langsam, Augenstein&Tanenbaum, Pearson, 1995
5. Algorithms + Data Structures &Programs:,N.Wirth, PHI
6. Fundamentals of Data Structures in C++: Horowitz Sahni& Mehta, Galgottia Pub.
7. Data structures in Java:, Thomas Standish, Pearson Education Asia

Online Learning Resources:

1. https://www.tutorialspoint.com/advanced_data_structures/index.asp
2. http://peterindia.net/Algorithms.html
3. https://www.youtube.com/playlist?list=PLDN4rrl48XKpZkf03iYFl-O29szjTrs_O

23A05M02	**INTRODUCTION TO ARTIFICIAL INTELLIGENCE**	**L**	**T**	**P**	**C**
		3	0	0	3

Course Objectives

- Understand the fundamental concepts and historical evolution of Artificial Intelligence.
- Learn various problem-solving approaches using AI algorithms.
- Gain insights into knowledge representation, reasoning, and planning techniques.
- Explore basic machine learning and neural network models.
- Familiarize with real-world AI applications and ethical implications.

Course Outcomes (COs)

CO No	Course Outcome	Bloom's Level
CO1	Explain the foundational principles and history of AI.	Understand (L2)
CO2	Apply AI techniques for problem-solving and decision-making.	Apply (L3)
CO3	Analyze search strategies and knowledge representation models.	Analyze (L4)
CO4	Evaluate the effectiveness of learning algorithms and intelligent agents.	Evaluate (L5)
CO5	Design simple AI-based systems or prototypes using AI concepts.	Create (L6)

Unit I: Introduction to Artificial Intelligence

Definition and applications of AI, History and evolution of AI, Intelligent agents – types and environments, AI techniques: Symbolic AI, Sub-symbolic AI

Unit II: Problem Solving and Search Strategies

Problem formulation, Uninformed search: BFS, DFS, Uniform Cost, Informed search: Greedy, A* search, Local search: Hill climbing, Simulated annealing, Constraint satisfaction problems

Unit III: Knowledge Representation and Reasoning

Propositional and First-Order Logic, Forward and backward chaining, Rule-based systems and ontologies, Semantic networks, frames, Uncertainty: Bayesian reasoning, fuzzy logic

Unit IV: Machine Learning Basics

Overview of supervised, unsupervised, reinforcement learning, Decision Trees, k-NN, Naïve Bayes, Basic concepts of neural networks and perceptron, Training and testing datasets, Evaluation metrics: Accuracy, precision, recall, F1-score

Unit V: Applications of AI and Ethical Issues

AI in Robotics, NLP, Vision, Healthcare, Finance, Chatbots and virtual assistants, AI biases, fairness, explainability, Social and legal implications of AI, Future trends: AGI, ethical AI

Textbooks

1. **Stuart Russell & Peter Norvig**, *Artificial Intelligence: A Modern Approach*, 4th Edition, Pearson
2. **Elaine Rich, Kevin Knight**, *Artificial Intelligence*, 3rd Edition, McGraw-Hill
3. **Dan W. Patterson**, *Introduction to Artificial Intelligence and Expert Systems*, PHI

Reference Books

1. **Kevin Murphy**, *Machine Learning: A Probabilistic Perspective*, MIT Press
2. **Nils J. Nilsson**, *The Quest for Artificial Intelligence*, Cambridge
3. **Tom Mitchell**, *Machine Learning*, McGraw-Hill

Online Courses

1. CourseraAI For Everyone – Andrew Ng

23A05M03	WEB TECHNOLOGIES	L	T	P	C
		3	0	0	3

Course Objectives:
The course is designed to Introduce the key technologies that have been developed as part of the birth and maturation of the World Wide Web.

Course Outcomes:
- Understand the Web essentials.
- Develop web pages using XHTML
- Apply style to web pages using CSS
- Write scripts for client side
- Develop and transform XML documents.

UNIT I
Web Essentials: Clients, Servers, and Communication, The Internet, Basic Internet protocols, WWW, HTTP request message, HTTP response message, Web clients, Web Servers, Case study.

UNIT II
Markup Languages: XHTML 1.0,An introduction to HTML, Basic XHTML syntax and semantics, fundamental HTML elements, Relative URLs, Lists, Tables, Frames, Forms, Defining XHTML‘s abstract syntax, Creating HTML documents.

UNIT III
Cascading Style Sheets: Introduction, features, core syntax, style sheets and HTML, style rule cascading and inheritance, text properties, Box model, normal flow box layout, beyond the normal flow, lists, tables, cursor styles.

UNIT IV
Client-side programming - JavaScript: Basic syntax, variables and data types, statements, operators, literals, functions, objects, Arrays, built-in objects, JavaScript debuggers.

UNIT V
Representing Web Data-XML: Documents and vocabularies, Versions and declaration, Namespaces, Ajax, DOM and SAX parsers, transforming XML documents, XPath, XSLT, Displaying XML documents in Web browsers.

Textbooks:
1. J.C. Jackson, Web technologies: A computer science perspective, Pearson.
2.

Reference Books:
1. Sebesta, Programming world wide web, Pearson.
2. Dietel and Nieto , Internet and World Wide Web –How to program, Pearson Education
3. Chris Bates , Web Programming, building internet applications, 2nd edition, WILEY, Dreamtech

Online Learning Resources:
http://getbootstrap.com/
https://www.w3schools.com/whatis/
https://nptel.ac.in/courses/106105084

23A05M04	INTRODUCTION TO DATA SCIENCE	L	T	P	C
		3	0	0	3

Course Objectives (COs)

The course aims to:

- Provide a foundational understanding of data science processes and applications.
- Introduce key tools and techniques such as Python, statistics, data cleaning, visualization, and machine learning.
- Develop practical skills in data analysis, interpretation, and data storytelling.
- Enable students to work on real-world datasets using data science techniques.
- Prepare students for advanced studies or industry roles in data science and analytics.

Course Outcomes

After completing this course, students will be able to:

CO No.	Course Outcome	BTL
CO1	Explain the data science lifecycle and its importance in business and research.	L2
CO2	Use Python and libraries like Pandas, NumPy, and Matplotlib for data handling.	L3
CO3	Perform data cleaning, transformation, and visualization effectively.	L3
CO4	Apply basic machine learning models for classification and regression.	L3
CO5	Interpret data analysis results and communicate findings clearly.	L4

Unit I: Introduction to Data Science: What is Data Science?,Role of Data Scientist, Data Science Process (Problem definition, data collection, preprocessing, modeling, evaluation), Applications of Data Science in different domains, Tools: Jupyter, Anaconda, Python/R Overview.

Unit II: Data Handling and Preprocessing: Introduction to NumPy and Pandas, Reading data from CSV, Excel, SQL, Data Wrangling: Missing values, duplicates, outliers, Data transformation: Scaling, encoding, Feature engineering basics.

Unit III: Data Visualization: Importance of visualization, Visualization libraries (Matplotlib, Seaborn), Histograms, Boxplots, Pairplots, Heatmaps, Dashboards and Storytelling with Data, Real-time data dashboards (Optional).

Unit IV: Statistical Foundations for Data Science: Descriptive Statistics, Probability and Probability Distributions, Inferential Statistics: Hypothesis Testing, Confidence Intervals, Correlation and Causation, Use of Scipy/Statsmodels for statistical analysis.

Unit V: Introduction to Machine Learning: Supervised vs Unsupervised Learning, Classification and Regression problems, Basic ML Algorithms: Linear Regression, Logistic Regression, KNN, Decision Trees, Model Evaluation Metrics: Accuracy, Precision, Recall, F1-Score, Overfitting and Underfitting.

Textbooks

1. **Joel Grus** – *Data Science from Scratch: First Principles with Python*, O'Reilly.
2. **Cathy O'Neil and Rachel Schutt** – *Doing Data Science*, O'Reilly.
3. **Wes McKinney** – *Python for Data Analysis*, O'Reilly.

Reference Books

1. **Jake VanderPlas** – *Python Data Science Handbook*, O'Reilly.
2. **Andreas Müller & Sarah Guido** – *Introduction to Machine Learning with Python.*
3. **Han, Kamber, & Pei** – *Data Mining: Concepts and Techniques*, Morgan Kaufmann.

Online Courses

NPTEL / SWAYAM:

- NPTEL: Introduction to Data Science
  - Instructor: Prof. RaghunathanRengasamy, IIT Madras

Coursera:

- **IBM Data Science Professional Certificate**
  Link: coursera.org
- **Introduction to Data Science in Python (University of Michigan)**
  Link: coursera.org

23A05M05	CLOUD COMPUTING	L	T	P	C
		3	0	0	3

Course Objectives:

- To explain the evolving computer model called cloud computing.
- To introduce the various levels of services that can be achieved by cloud.
- To describe the security aspects in cloud.

Course Outcomes (CO):

After completion of the course, students will be able to

- Ability to create cloud computing environment
- Ability to design applications for Cloud environment
- Design & amp; develop backup strategies for cloud data base don features.
- Use and Examine different cloud computing services.
- Apply different cloud programming model asperneed.

UNIT-I

Introduction to cloud computing: Introduction, Characteristics of cloud computing, Cloud Models, Cloud Services Examples, Cloud Based services and applications

Cloud concepts and Technologies: Virtualization, Load balancing, Scalability and Elasticity, Deployment, Replication, Monitoring, Software defined, Network function virtualization, Map Reduce, Identity and Access Management, services level Agreements, Billing.

Cloud Services and Platforms: Compute Services, Storage Services, Database Services, Application services, Content delivery services, Analytics Services, Deployment and Management Services, Identity and Access Management services, Open Source Private Cloud software.

UNIT-II

Hadoop MapReduce: Apache Hadoop, Hadoop Map Reduce Job Execution, Hadoop Schedulers, Hadoop Cluster setup.

Cloud Application Design: Reference Architecture for Cloud Applications, Cloud Application Design Methodologies, Data Storage Approaches.

Python Basics: Introduction, Installing Python, Python data Types & Data Structures, Control flow, Function, Modules, Packages, File handling, Date/Time Operations, Classes.

UNIT-III

Python for Cloud: Python for Amazon web services, Python for Google Cloud Platform, Python for windows Azure, Python for MapReduce, Python packages of Interest, Python web Application Frame work, Designing a RESTful web API.

Cloud Application Development in Python :Design Approaches, Image Processing APP, Document Storage App, MapReduce App, Social Media Analytics App.

UNIT-IV

Big Data Analytics: Introduction, Clustering Big Data, Classification of Bigdata Recommendation of Systems. Multimedia Cloud: Introduction, Case Study: Live video Streaming App, Streaming Protocols, case Study: Video Transcoding App.

Cloud Application Benchmarking and Tuning: Introduction, Workload Characteristics, Application Performance Metrics, Design Considerations for a Benchmarking Methodology, Benchmarking Tools, Deployment Prototyping, Load Testing & Bottleneck Detection case Study, Hadoop benchmarking case Study.

UNIT-V

Cloud Security: Introduction, CSA Cloud Security Architecture, Authentication, Authorization, Identity Access Management, Data Security, Key Management, Auditing.

Cloud for Industry, Healthcare & Education: Cloud Computing for Health care, Cloud computing for Energy Systems, Cloud Computing for Transportation Systems, Cloud Computing for Manufacturing Industry, Cloud computing for Education.

Migrating into a Cloud: Introduction, Broad Approaches to migrating into the cloud, the seven– step model of migration into a cloud.

Organizational readiness and Change Management in The Cloud Age: Introduction, Basic concepts of Organizational Readiness, Drivers for changes: A frame work to comprehend the competitive environment, common change management models, change management maturity models, Organizational readiness self – assessment.

Legal Issues in Cloud Computing: Introduction, Data Privacy and security Issues, cloud contracting models, Jurisdiction a issues raised by virtualization and data location, commercial and
Business considerations, Special Topics.

Textbooks:

1. Cloud computing A hands-on Approach‖ By ArshdeepBahga, Vijay Madisetti, Universities Press, 2016
2. Cloud Computing Principles and Paradigms: By Raj Kumar Buyya, James Broberg, Andrzej, Goscinski, Wiley, 2016.

Reference Books:

1. Mastering Cloud Computing by RajkumarBuyya, Christian Vecchiola, SThamaraiSelvi, TMH
2. Cloud computing A Hands-On Approach by ArshdeepBahga and Vijay Madisetti.
3. Cloud Computing: A Practical Approach, Anthony T. Velte, Toby J. Velte, Robert Elsenpeter, Tata McGraw Hill, rp2011.
4. Enterprise Cloud Computing, Gautam Shroff, Cambridge University Press, 2010.
5. Cloud Application Architectures: Building Applications and Infrastructure in the Cloud, George Reese, O _Reilly, SPD, rp2011.
6. Essentials of Cloud Computing by K. Chandrasekaran. CRC Press.

23A05M01P	DATA STRUCTURES & ALGORITHMS LAB	L	T	P	C
		0	0	3	1.5

Course Objectives:

The objectives of the course is to

- acquire practical skills in constructing and managing Data structures
- apply the popular algorithm design methods in problem-solving scenarios

Course Outcomes:

After completion of the course, students will be able to

- Design and develop programs to solve real world problems with the popular algorithm design methods. (L5)
- Demonstrate an understanding of Non-Linear data structures by developing implementing the operations on AVL Trees, B-Trees, Heaps and Graphs. (L2)
- Critically assess the design choices and implementation strategies of algorithms and data structures in complex applications. (L5)
- Utilize appropriate data structures and algorithms to optimize solutions for specific computational problems. (L3)
- Compare the performance of different of algorithm design strategies (L4)

Experiments covering the Topics:

- Operations on AVL trees, B-Trees, Heap Trees
- Graph Traversals
- Sorting techniques
- Finding Biconnected components in a graph
- Shortest path algorithms using greedy Method
- 0/1 Knapsack Problem using Dynamic Programming and Backtracking
- Travelling Salesperson problem using Branch and Bound
- N-Queens Problem using Backtracking
- Job Sequencing using Branch and Bound

Sample Programs:

1. Construct an AVL tree for a given set of elements which are stored in a file. And implement insert and delete operation on the constructed tree. Write contents of tree into a new file using in-order.
2. Construct B-Tree an order of 5 with a set of 100 random elements stored in array. Implement searching, insertion and deletion operations.
3. Construct Min and Max Heap using arrays, delete any element and display the content of the Heap.
4. Implement BFT and DFT for given graph, when graph is represented by
   a) Adjacency Matrix b) Adjacency Lists
5. Write a program for finding the biconnected components in a given graph.
6. Implement Quick sort and Merge sort and observe the execution time for various input sizes (Average, Worst and Best cases).
7. Compare the performance of Single Source Shortest Paths using Greedy method when the graph is represented by adjacency matrix and adjacency lists.
8. Implement Job Sequencing with deadlines using Greedy strategy.
9. Write a program to solve 0/1 Knapsack problem Using Dynamic Programming.
10. Implement N-Queens Problem Using Backtracking.
11. Use Backtracking strategy to solve 0/1 Knapsack problem.
12. Implement Travelling Sales Person problem using Branch and Bound approach.

Reference Books:

1. Fundamentals of Data Structures in C++, Horowitz Ellis, SahniSartaj, Mehta, Dinesh, 2nd Edition, Universities Press
2. Computer Algorithms/C++ Ellis Horowitz, SartajSahni, SanguthevarRajasekaran, 2nd Edition, University Press
3. Data Structures and program design in C, Robert Kruse, Pearson Education Asia
4. An introduction to Data Structures with applications, Trembley & Sorenson, McGraw Hill

Online Learning Resources:

1. http://cse01-iiith.vlabs.ac.in/
2. http://peterindia.net/Algorithms.html

23A05M03P	WEB TECHNOLOGIES LAB	L	T	P	C
		0	0	3	1.5

Course Objectives:

- Learn website development using HTML, CSS, JavaScript.
- Understand the concepts of responsive web development using the bootstrap framework
- Make use of the JQueryjavascript library to provide interactiveness to the websites.
- Discover how to use Google Charts to provide a better way to visualize data on a website
- Learn Content Management Systems to speed the development process

Course Outcomes (CO):

After completion of the course, students will be able to

- Construct web sites with valid HTML, CSS, JavaScript
- Create responsive Web designs that work on phones, tablets, or traditional laptops and widescreen monitors.
- Develop websites using jQuery to provide interactivity and engaging user experiences
- Embed Google chart tools in a website for better visualization of data.
- Design and develop web applications using Content Management Systems like WordPress

Sample Programs:

1. Create a Basic HTML document
2. Create your Profile Page
3. Create a Class Timetable (to merge rows/columns, use rowspan/colspan)
4. Create a Student Hostel Application Form
5. Make the Hostel Application Form designed in Module -4 beautiful using CSS (add colors,backgrounds, change font properties, borders, etc.)
6. Style the Hostel Application Form designed in Module-5still more beautiful using Bootstrap
7. Analyse various HTTP requests (initiators, timing diagrams, responses) and identify problems if any.
8. Design a simple calculator using JavaScript to perform sum, product, difference, and quotient operations:
9. Design& develop a Shopping Cart Application with features including Add Products, Update Quantity, Display Price(Sub-Total & Total), Remove items/products from the cart.
10. Validate all Fields and Submit the Hostel Application Form designed in Module-6 using JQuery
11. Develop an HTML document to illustrate each chart with real-time examples.
12. Develop an E-learning website using any CMS(for example WordPress)

References:

1. Deitel and Deitel and Nieto, ―Internet and World Wide Web - How to Program‖, PrenticeHall, 5th Edition, 2011.

2. Web Technologies, Uttam K. Roy, Oxford Higher Education., 1st edition, 10th impression, 2015.

3. Stephen Wynkoop and John Burke ―Running a Perfect Website‖, QUE, 2nd Edition,1999.

4. Jeffrey C and Jackson, ―Web Technologies A Computer Science PerspectivePearsonEducation, 2011.

5. Gopalan N.P. and Akilandeswari J., ―Web Technology, Prentice Hall of India, 2011.

Online Learning Resources/Virtual Labs:

a. HTML: https://html.spec.whatwg.org/multipage/
b. HTML: https://developer.mozilla.org/en-US/docs/Glossary/HTML5
c. CSS: https://www.w3.org/Style/CSS/
d. Bootstrap - CSS Framework: https://getbootstrap.com/
e. BrowserDeveloperTools:https://developer.mozilla.org/enUS/docs/Learn/Common_questions/What_ are_browser_developer_tools
f. Javascript: https://developer.mozilla.org/en-US/docs/Web/JavaScript
g. JQuery: https://jquery.com
h. Google Charts: https://developers.google.com/chart
i. Wordpress: https://wordpress.com

23A05M06	INTRODUCTION TO QUANTUM COMPUTING	L	T	P	C
		3	0	0	3

Course Objectives

- Understand quantum mechanics principles in computing.
- Explore qubits, quantum gates, and circuits.
- Analyze the advantages of quantum algorithms.
- Study entanglement, superposition, and interference.
- Investigate real-world applications and platforms.

Course Outcomes (COs)

CO Code	Description	Bloom's Level
CO1	Explain concepts of quantum mechanics	Understand(L1)
CO2	Illustrate quantum gates/circuits	Apply(L3)
CO3	Analyze algorithms (e.g., Shor, Grover)	Analyze(L4)
CO4	Evaluate communication protocols	Evaluate(L5)
CO5	Develop quantum programs on IBM Q	Create(L6)

Unit I: Qubits and Quantum Foundations

Classical Bits vs Qubits, Postulates of Quantum Mechanics, Superposition and Probability Amplitudes, Dirac Notation (Bra-Ket), Bloch Sphere Representation, Measurement in Quantum Systems, Quantum State Collapse

Unit II: Quantum Gates and Circuits

Quantum Logic Gates: Pauli-X, Y, Z; Hadamard (H); Phase (S, T), Controlled Gates: CNOT, Toffoli, Unitary and Reversible Operations, Quantum Circuit Representation, Building Basic Quantum Circuits, Quantum Parallelism and Interference, No-Cloning Theorem and Quantum Gate Simulation

Unit III: Quantum Algorithms

Need for Quantum Algorithms, Deutsch and Deutsch-Jozsa Algorithm, Grover‘s Search Algorithm (Quadratic Speed-up), Shor‘s Factoring Algorithm (Exponential Speed-up), Simon‘s Algorithm (Overview), Complexity Comparison: Classical vs Quantum

Unit IV: Entanglement and Quantum Communication

Quantum Entanglement and Bell States, Quantum Teleportation Protocol, Superdense Coding, Quantum Key Distribution: BB84, E91 Protocols, Decoherence and Quantum Noise, Quantum Error Correction Codes (Bit Flip, Phase Flip, Shor Code)

Unit V: Quantum Platforms and Applications

Overview of Quantum Programming Platforms: IBM Qiskit, Microsoft Q#, Google Cirq, Quantum Circuit Simulation using Qiskit, Executing Code on Real Quantum Hardware (IBM Q). Quantum Applications in:Cryptography, Machine Learning, Optimization, Chemistry, Building and Testing a Sample Quantum Program

Textbooks

1. **Michael A. Nielsen & Isaac L. Chuang** – *Quantum Computation and Quantum Information*, Cambridge University Press, 10th Anniversary Edition.
2. **David McMahon** – *Quantum Computing Explained*, Wiley.
3. **Bernhardt, Chris** – *Quantum Computing for Everyone*, MIT Press.

Reference Books

1. **Mermin, N. David** – *Quantum Computer Science: An Introduction*, Cambridge University Press.
2. **William H. Press et al.** – *Numerical Recipes in C: The Art of Scientific Computing* (for simulation background)
3. **Rieffel&Polak** – *Quantum Computing: A Gentle Introduction*, MIT Press.

Online Courses & Resources

Platform	Course Name	Link
IBM Qiskit	IBM Qiskit Textbook	Hands-on, beginner-friendly curriculum for quantum programming
Coursera	*Quantum Mechanics for Scientists and Engineers* by Stanford (Leonard Susskind)	Link

23A05M07	MATHEMATICAL FOUNDATIONS FOR QUANTUM COMPUTING	L	T	P	C
		3	0	0	3

Course Objectives

- Cover linear algebra & complex vector spaces.
- Model quantum states mathematically.
- Apply probability theory to measurements.
- Study eigenvalues and transformations.
- Prepare for algorithm analysis with rigor.

Course Outcomes (COs)

CO Code	Description	Bloom's Level
CO1	Understand complex numbers & linear algebra	Understand
CO2	Apply vector space & Dirac notation	Apply
CO3	Analyze unitary &Hermitian operators	Analyze
CO4	Evaluate eigen decomposition in quantum ops	Evaluate
CO5	Create models using probability theory	Create

Unit I: Foundations of Complex Vector Spaces

Complex Numbers: Polar form, Euler's formula, Vectors in $\mathbb{C}^n$, Inner Product Spaces, Dirac Notation (Bra-Ket), Hilbert Space: Definitions and Properties, Orthogonality and Completeness, Norms, Metrics, and Distance in Complex Spaces

Unit II: Matrix Algebra and Operators

Matrix Multiplication and Linear Transformations, Special Matrices: Identity, Diagonal, Unitary, Tensor Products of Matrices and Vectors, Kronecker Product Applications, Unitary and Invertible Operators, Quantum Gates as Linear Operators

Unit III: Eigen Concepts and Quantum Observables

Eigenvalues and Eigenvectors, Hermitian Operators and Spectral Theorem, Quantum Observables and Expectation Values, Commutators and Compatibility, Measurement Operators and Matrix Diagonalization, Applications in Quantum Gate Analysis

Unit IV: Quantum Measurement & Probability

Basics of Probability Theory in Quantum Systems, Born's Rule and Measurement Probabilities, Projection Postulate, Density Matrix Formalism, Mixed States and Pure States, Trace, Partial Trace, and Operator Sums

Unit V: Advanced Structures in Quantum Math *(CO5 – Create)*

Group Theory Basics: Symmetry, Permutations, Pauli Group, Clifford Group, and their roles, Fourier Transform in Quantum Context, Gram-Schmidt Orthogonalization, Lie Groups and Lie Algebras, Use of Lie Algebra in Hamiltonian Formulation

Textbooks

1. **Nielsen & Chuang –** *Quantum Computation and Quantum Information*, Cambridge University Press
2. **Brian C. Hall –** *Quantum Theory for Mathematicians*, Springer
3. **T.S. Blyth & E.F. Robertson** – *Basic Linear Algebra*, Springer

Reference Books

1. **Roman S. –** *Advanced Linear Algebra*, Springer
2. **Axler, Sheldon** – *Linear Algebra Done Right*, Springer
3. **Shankar, R.** – *Principles of Quantum Mechanics*, Springer
4. **W. Greiner –** *Quantum Mechanics: An Introduction*, Springer

Online Courses & Resources

Platform	Course Name	Link
MIT OpenCourseWare	*Linear Algebra (Gilbert Strang)*	Link
edX	*Mathematics for Quantum Computing* by TUDelft	Link
Khan Academy	*Linear Algebra, Probability & Statistics*	Link
Quantum Country	*Spaced Repetition & Essays on Quantum Math*	Link

23A05M08	**QUANTUM ALGORITHMS**	**L**	**T**	**P**	**C**
		3	0	0	3

Course Objectives

- Understand algorithm design principles in the quantum domain.
- Use mathematical tools such as linear algebra and probability in algorithm analysis.
- Implement quantum algorithms and compare them with classical equivalents.
- Study key applications in cryptography, database search, and optimization.

Course Outcomes (COs)

CO Code	Description	Bloom's Level
CO1	Understand quantum algorithm building blocks	Understand
CO2	Analyze well-known quantum algorithms	Analyze
CO3	Apply quantum algorithms to application domains	Apply
CO4	Evaluate efficiency and complexity of algorithms	Evaluate
CO5	Create and simulate quantum algorithms	Create

Unit I: Mathematical Tools for Quantum Algorithms

Review of Complex Numbers & Linear Algebra for Quantum Computing, Inner Product Spaces, Hilbert Spaces, Dirac Notation and Interpretations, Quantum State Vectors and Superposition, Overview of Quantum Gates and Operators, Building Block Concepts for Algorithmic Design

Unit II: Quantum Circuits and Operations

Quantum Gates: X, H, Z, CNOT, Toffoli, Quantum Circuits: Representation and Simulation, Quantum Teleportation Protocol, Circuit-based Measurement and State Collapse, Reversible Computing and Unitary Evolution, Applying Circuits to Small-scale Problems

Unit III: Search and Oracle-Based Algorithms

Deutsch's Algorithm: Problem and Solution Strategy, **Simon's Algorithm**: Period-finding and Speed-up Over Classical, **Grover's Search Algorithm**: Amplitude Amplification, Oracle Construction in Grover's Algorithm, Circuit Analysis and Complexity Comparison, Limitations and Applications in Database Search

Unit IV: Fourier-Based & Cryptographic Algorithms ***(CO4 – Evaluate)***

Quantum Fourier Transform (QFT): Theory and Circuit, **Phase Estimation Algorithm**: Foundations and Usage, **Shor's Algorithm**: Integer Factorization and Discrete Logarithms, Modular Arithmetic and Period Finding, Cryptographic Implications of Quantum Algorithms, Efficiency Analysis vs Classical RSA Factorization

Unit V: Advanced & Hybrid Quantum Algorithms ***(CO5 – Create)***

Variational Quantum Eigensolver (VQE), Quantum Approximate Optimization Algorithm (QAOA), Quantum Machine Learning (QML): Classification & Clustering, Hybrid Quantum-

Classical Models, IBM Qiskit&Cirq for Implementation, Building Custom Quantum Algorithms for NISQ Devices

Textbooks

1. **Michael A. Nielsen & Isaac L. Chuang** – *Quantum Computation and Quantum Information*, Cambridge University Press
2. **Cristopher Moore & Stephan Mertens** – *The Nature of Computation*, Oxford University Press
3. **Eleanor G. Rieffel& Wolfgang Polak** – *Quantum Computing: A Gentle Introduction*, MIT Press

Reference Books

1. **Gideon Amir** – *Quantum Algorithms via Linear Algebra*, MIT Press
2. **S. Jordan –** *Quantum Algorithm Zoo*, [Online repository]
3. **T. G. Wong –** *Quantum Algorithm Design Techniques*
4. **Roland, Cerf –** *Quantum Search Algorithms*, Springer

Online Courses & Resources

Platform	Course Name	Link
edX (MIT)	*Quantum Algorithms for Cybersecurity*	Link
Coursera	*Quantum Computing* by University of London	Link
Qiskit Textbook	*Algorithms & Quantum Machine Learning Modules*	Link
Braket (AWS)	*Quantum Computing Developer Tools & Tutorials*	Link

23A05M09	QUANTUM INFORMATION AND COMMUNICATION	L	T	P	C
		3	0	0	3

Course Objectives

- Understand the principles of quantum information theory.
- Explore quantum entropy, fidelity, and mutual information.
- Study quantum communication protocols and networks.
- Analyze quantum key distribution and cryptographic security.
- Implement protocols like teleportation and superdense coding.

Course Outcomes (COs)

CO Code	Description	Bloom's Level
CO1	Understand quantum information concepts	Understand
CO2	Apply quantum communication protocols	Apply
CO3	Analyze fidelity, entropy, and data transfer limits	Analyze
CO4	Evaluate quantum cryptographic techniques	Evaluate
CO5	Create and simulate quantum communication models	Create

Unit I: Quantum Information Basics

Classical vs Quantum Information, Density matrices and mixed states, Quantum entropy and Shannon entropy, Von Neumann entropy, Quantum data compression,

Unit II: Quantum Communication Protocols

Quantum teleportation, Superdense coding, Quantum repeaters and communication channels, No- cloning theorem, Quantum channel capacity

Unit III: Fidelity, Distance & Information Theory

Fidelity and trace distance, Quantum mutual information, Holevo bound, Information trade-offs in communication, Channel noise and error modeling

Unit IV: Quantum Cryptography

Principles of quantum cryptography, BB84 and B92 key distribution protocols, Eavesdropping and security analysis, Quantum bit commitment, Post-quantum cryptography relevance

Unit V: Applications & Tools

Quantum internet: architecture and challenges, Networked quantum systems, Simulation using Qiskit, NetSquid, QuTiP, IBM Q Network and cloud-based setups, Practical implementation of QKD in simulation

Textbooks

1. Michael A. Nielsen & Isaac L. Chuang – *Quantum Computation and Quantum Information*, Cambridge University Press
2. Mark M. Wilde – *Quantum Information Theory*, Cambridge University Press
3. John Watrous – *The Theory of Quantum Information*, Cambridge University Press

Reference Books

1. Peter W. Shor – *Foundations of Quantum Computing* (Lecture notes)
2. Charles H. Bennett & Gilles Brassard – *Original Papers on QKD (BB84)*
3. Stephanie Wehner – *Quantum Communication Networks*, arXiv

Online Courses & Resources

Platform	Course Name	Link
Coursera	*Quantum Cryptography* by University of Geneva	Coursera Link
edX	*Quantum Information Science I* (Harvard/MIT)	edX Course
Qiskit	*Quantum Information Applications in Qiskit Textbook*	Qiskit Info
QuTech	*Quantum Internet Tutorials & Tools*	QuTech

23A05M10	QUANTUM MACHINE LEARNING (QML)	L	T	P	C
		3	0	0	3

Course Objectives

- Introduce the fundamentals of quantum-enhanced machine learning.
- Understand quantum data encoding and kernel methods.
- Explore quantum algorithms for supervised and unsupervised learning.
- Analyze hybrid quantum-classical architectures.
- Implement QML models using frameworks like Qiskit and PennyLane.

Course Outcomes (COs)

CO Code	Description	Bloom's Level
CO1	Understand foundations of quantum machine learning	Understand
CO2	Apply QML algorithms to datasets	Apply
CO3	Analyze quantum kernels, data encoding, and models	Analyze
CO4	Evaluate hybrid quantum-classical models	Evaluate
CO5	Create and simulate QML models using frameworks	Create

Unit I: Introduction to QML

Need for QML: Why quantum for ML?,Classical vs quantum machine learning, Quantum states as information carriers, Data encoding: amplitude, angle, basis encoding, Introduction to quantum feature space.

Unit II: QML Algorithms – Supervised Learning

Quantum classifiers (quantum SVMs, qNN), Quantum perceptron, Variational quantum classifiers (VQC), Quantum kernels, Cost functions in quantum models

Unit III: QML Algorithms – Unsupervised Learning

Quantum k-means and clustering, Quantum PCA, Quantum generative models (QGANs), Dimensionality reduction and similarity metrics, Performance analysis and limitations

Unit IV: Hybrid Models & Optimization *(CO4 – Evaluate)*

Variational Quantum Circuits (VQCs), Hybrid quantum-classical training loops, Barren plateaus and optimization issues, Quantum gradient descent and parameter shift rule, Comparative study of classical and QML models

Unit V: QML Tools and Case Studies *(CO5 – Create)*

Implementing QML with Qiskit Machine Learning, PennyLane and TensorFlow Quantum integration, Case studies: quantum-enhanced fraud detection, NLP, Quantum datasets and benchmark models, Project: design a small QML application

Textbooks

1. Maria Schuld, Francesco Petruccione – *Machine Learning with Quantum Computers*, Springer
2. Peter Wittek – *Quantum Machine Learning: What Quantum Computing Means to Data Mining*, Academic Press

Reference Books

1. Jacob Biamonte – *Quantum Machine Learning*, Nature, 2017
2. Seth Lloyd – *Quantum algorithms for supervised/unsupervised learning* (Research papers)
3. VojtěchHavlíček – *Supervised Learning with Quantum-Enhanced Feature Spaces*, Nature, 2019

Online Courses & Resources

Platform	Course Name	Link
edX	*Quantum Machine Learning* by UTS	edX Course
Qiskit	*Qiskit Machine Learning Module*	Qiskit ML
Xanadu	*QML with PennyLane (Free online textbook)*	PennyLane QML Book
Coursera	*Quantum Machine Learning* by University of Toronto	Coursera

23A05M06P	**QUANTUM ALGORITHMS LAB**	**L**	**T**	**P**	**C**
		0	0	3	1.5

Experiments (12)

1. Deutsch Algorithm
2. Deutsch-Jozsa
3. Grover's Algorithm
4. QFT Visualization
5. Shor's Algorithm
6. QRNG Implementation
7. Bell State Entanglement
8. Bernstein-Vazirani Algorithm
9. Quantum Teleportation
10. Phase Estimation
11. Circuit Simulation
12. Mini-Project: RSA Key Breaking

23A05M11P	QUANTUM PROGRAMMING AND SIMULATION LAB	L	T	P	C
		0	0	3	1.5

Experiments (12)

1. State Vector Simulation (Qiskit)
2. Bell State Implementation
3. Deutsch-Jozsa Circuit
4. Grover's Search in Qiskit
5. QFT Circuit in Python
6. Shor Algorithm Simulation
7. Quantum Teleportation in Code
8. VQE (Hybrid Circuit)
9. QAOA Simulation
10. Quantum Random Number Generator
11. Comparison: Real vs Simulated Runs
12. Mini-Project: Quantum Password Cracker

Textbooks & References

- Michael Nielsen & Isaac Chuang – *Quantum Computation and Quantum Information*
- Eric R. Johnston et al. – *Programming Quantum Computers*
- David McMahon – *Quantum Computing Explained*
- Gilbert Strang – *Introduction to Linear Algebra*
- Sarah Kaiser & Chris Granade – *Learn Quantum Computing with Python and Q#*

Online Resources

- IBM Qiskit Textbook: https://qiskit.org/learn
- Microsoft Q# Documentation: https://learn.microsoft.com/en-us/azure/quantum/
- Coursera: *Introduction to Quantum Computing*
- edX: *Quantum Computing Fundamentals*, *Quantum Algorithms*

(23A05M12) **Foundations of Quantum Technologies**

Course Objectives

- Introduce the fundamental quantum mechanics concepts essential for quantum technologies.
- Build strong mathematical foundations for quantum state modeling.
- Develop understanding of superposition, entanglement, and measurement.
- Explain the physical principles behind quantum devices.
- Prepare students for advanced studies in quantum computation, communication, sensing, and materials.

Course Outcomes (COs)

CO Code	Description	Bloom's Level
CO1	Understand postulates of quantum mechanics for quantum technologies	Understand
CO2	Apply linear algebra and Dirac notation to quantum state analysis	Apply
CO3	Analyze superposition, entanglement, and measurement processes	Analyze
CO4	Evaluate quantum systems through operators and probability amplitudes	Evaluate
CO5	Create mathematical models for simple quantum systems	Create

Syllabus Content

UNIT I – Quantum Mechanics Foundations*(Cognitive Level: Understand)*

Classical vs Quantum systems, Wave-particle duality, Schrödinger equation (Time-dependent and Time-independent), Postulates of Quantum Mechanics, Quantum states and state vectors, Complex Hilbert spaces, Dirac notation (Bra-Ket notation), Probabilistic interpretation of quantum mechanics

UNIT II – Linear Algebra for Quantum Systems*(Cognitive Level: Apply)*

Complex vector spaces and inner products, Orthonormal basis and orthogonality, Linear operators and transformations, Unitary operators and Hermitian operators, Tensor products for multi-qubit systems, Eigenvalues and Eigenvectors, Commutators and anti-commutators, Representing quantum states with matrices

UNIT III – Superposition, Measurement, and Entanglement*(Cognitive Level: Analyze)*

Principle of superposition, Measurement postulate, Probability amplitudes and Born rule, State collapse upon measurement, Entanglement and Bell states, EPR paradox and non-locality, Density matrices and mixed states, Quantum decoherence

UNIT IV – Operators and Quantum Dynamics*(Cognitive Level: Evaluate)*

Time evolution operators, Hamiltonian and energy eigenstates, Quantum harmonic oscillator(brief overview), Unitary evolution and Schrödinger equation solutions, Quantum tunnelling, Adiabatic theorem basics, Operator algebra in quantum systems, Expectation values and observables

UNIT V – Quantum Technologies Building Blocks*(Cognitive Level: Create)*

Basic qubit systems (spin-1/2, photon polarization, superconducting qubits), Two-level quantum systems modelling, Bloch sphere representation, Quantum logic gates fundamentals, Multi-qubit systems: controlled operations, Introduction to decoherence and quantum error correction, Quantum technologies: hardware platforms overview, Basic quantum circuit modeling using simulators (Qiskit or Q# demo examples)

Textbooks

1□. Michael A. Nielsen & Isaac L. Chuang – *Quantum Computation and Quantum Information*
2□. N. David Mermin – *Quantum Computer Science: An Introduction*
3□. David McMahon – *Quantum Computing Explained* (Wiley)

Reference Books

1□. Griffiths, D. – *Introduction to Quantum Mechanics*
2□. Sakurai, J.J. – *Modern Quantum Mechanics*
3□. ohnWatrous – *The Theory of Quantum Information*
4□. V.K. Krishnan – *Linear Algebra and its Applications to Quantum Computing*

Online Courses & Resources

Platform	Course Title
MIT OpenCourseWare	Quantum Physics I, II (MIT OCW 8.04 & 8.05)
edX (Berkeley)	Quantum Mechanics and Quantum Computation

(23A05M13) **Solid State Physics for Quantum Technologies**

Course Objectives

- Understand fundamental solid-state physics principles relevant to quantum technologies.
- Study the electronic properties of materials used in quantum hardware.
- Explore quantum confinement and nanostructures for qubit implementation.
- Analyze crystal structures, band theory, and defects influencing quantum devices.
- Build foundations for material selection and engineering for quantum systems.

Course Outcomes (COs)

CO Code	**Description**	**Bloom's Level**
CO1	Understand crystal structures and band theory	Understand
CO2	Apply knowledge of semiconductors, insulators, and conductors in quantum materials	Apply
CO3	Analyze quantum confinement effects and low-dimensional systems	Analyze
CO4	Evaluate defects, phonons, and interactions in solid-state systems	Evaluate
CO5	Create models for quantum device material systems	Create

Syllabus Content

UNIT I – Crystal Structure and Electronic Properties***(Cognitive Level: Understand)***

Crystal lattices and unit cells, Bravais lattices, Miller indices, Reciprocal lattice and Brillouin zones, Atomic bonding in solids (covalent, ionic, metallic, van der Waals), X-ray diffraction and crystal structure determination, Electronic structure of solids, Free electron theory, Energy bands: metals, semiconductors, and insulators

UNIT II – Semiconductor Physics for Quantum Devices***(Cognitive Level: Apply)***

Intrinsic and extrinsic semiconductors, Charge carriers: electrons, holes, effective mass, Carrier concentration and Fermi level, p-n junctions and semiconductor heterostructures, Quantum wells and quantum dots as qubits, Superconductors and Josephson junctions, Semiconductor fabrication basics, Materials for quantum hardware: Si, GaAs, diamond NV centers, topological insulators

UNIT III – Quantum Confinement and Low-Dimensional Systems***(Cognitive Level: Analyze)***

Quantum size effects: nanowires, nanotubes, 2D materials, Quantum dots: discrete energy levels, Quantum Hall effect, Topological quantum materials, Spintronics and spin qubits, Quantum confinement in superconducting qubits, Heterostructure-based quantum devices, Valleytronics and emerging 2D materials (MoS_2 , graphene)

UNIT IV – Lattice Vibrations and Phonon Interactions***(Cognitive Level: Evaluate)***

Lattice vibrations and phonons, Heat capacity and thermal conductivity of solids, Electron-phonon interaction, Decoherence in solid-state qubits due to phonons, Magnetic impurities and Kondo effect, Defects and dislocations in crystals, Dopants and quantum impurity systems, Nuclear spin environments and coherence times

UNIT V – Materials for Quantum Technologies***(Cognitive Level: Create)***

Material engineering for superconducting qubits, NV centers in diamond for quantum sensing, Topological materials for robust qubits, Photonic crystal materials for optical qubits, Hybrid quantum systems: coupling different materials, Fabrication challenges and material purity, Advances in quantum materials research, Designing material systems for long coherence time

Textbooks 1□. Charles Kittel – *Introduction to Solid State Physics*
1. Michael A. Nielsen & Isaac Chuang – *Quantum Computation and Quantum Information*
3□. Simon L. Altmann – *Band Theory of Solids*

Reference Books 1□. Ashcroft &Mermin – *Solid State Physics*
2□. Yu & Cardona – *Fundamentals of Semiconductors: Physics and Materials Properties*
3□. David Awschalom – *Semiconductor Spintronics and Quantum Computation*
4□. Dieter Vollhardt – *Introduction to the Theory of Many-Body Systems*

Online Courses & Resources

Platform	**Course Title**
MIT OpenCourseWare	Solid State Physics (MIT 8.231)
edX	Quantum Materials and Devices (U. Tokyo)
Coursera	Quantum Materials (ÉcolePolytechnique)

(23A05M14) Quantum Optics Prerequisites for Quantum Technologies

Course Objectives

- Introduce fundamentals of light-matter interaction relevant for quantum technologies.
- Explain the quantization of electromagnetic fields.
- Study the role of photons as quantum information carriers.
- Explore coherent states, squeezed states, and single-photon sources.
- Prepare for quantum sensing, communication, and photonic quantum computing applications.

Course Outcomes (COs)

CO Code	Description	Bloom's Level
CO1	Understand quantum nature of light	Understand
CO2	Apply Maxwell's equations to optical fields	Apply
CO3	Analyze interaction of photons with matter	Analyze
CO4	Evaluate coherence, squeezing, and quantum noise	Evaluate
CO5	Create models for photonic quantum systems	Create

Syllabus Content

UNIT I – Classical and Quantum Description of Light ***(Cognitive Level: Understand)***

Review of electromagnetic waves, Maxwell's equations for light propagation, Plane waves, polarization, Poynting vector, Classical interference, diffraction, coherence, Blackbody radiation & Planck's hypothesis, Photoelectric effect, Photons as quantized light energy, Introduction to quantum theory of radiation

UNIT II – Quantization of Electromagnetic Field ***(Cognitive Level: Apply)***

Harmonic oscillator quantization, Field quantization in free space, Photon number (Fock) states, Coherent states and classical-quantum correspondence, Vacuum fluctuations and zero-point energy, Single-mode vs multi-mode quantization, Spontaneous and stimulated emission, Quantum field operators and commutation relations

UNIT III – Light-Matter Interaction ***(Cognitive Level: Analyze)***

Two-level atom model, Absorption, stimulated emission, spontaneous emission, Einstein coefficients, Rabi oscillations, Jaynes-Cummings model, Resonant and non-resonant interaction, Cavity Quantum Electrodynamics (Cavity-QED), Atom-photon entanglement

UNIT IV – Quantum Coherence and Quantum Noise ***(Cognitive Level: Evaluate)***

Classical vs quantum coherence, First- and second-order coherence functions, Photon antibunching, Hanbury Brown and Twiss experiment, Quantum squeezing of light, Phase-sensitive amplification, Quantum noise, shot noise, and standard quantum limit, Quantum nondemolition measurements

UNIT V – Quantum Photonics Applications ***(Cognitive Level: Create)***

Single-photon sources (quantum dots, NV centers, SPDC), Entangled photon pair generation, Photonic qubits and linear optical quantum computing, Quantum key distribution with photons, Photonic integrated circuits, Quantum sensors based on squeezed light, Quantum metrology using entangled photons, Designing experiments for quantum optics labs

Textbooks

1□. Mark Fox – *Quantum Optics: An Introduction* 2□. Rodney Loudon – *The Quantum Theory of Light* 3□. M. O. Scully & M. S. Zubairy – *Quantum Optics*

Reference Books 1□. Stephen Barnett – *Quantum Information*
2□. Peter Meystre – *Elements of Quantum Optics*
3□. Michel Le Bellac – *Quantum Physics*
4□. D. F. Walls & G. J. Milburn – *Quantum Optics*

Online Courses & Resources

Platform	**Course Title**
MIT OpenCourseWare	Quantum Optics (MIT 8.421)
edX	Principles of Photonics (EPFL)
Coursera	Quantum Optics 1 & 2 (U. Rochester)
YouTube	Quantum Optics Lectures (Various universities)

(23A05M15) Introduction to Quantum Communication

Course Objectives

- Introduce fundamental principles of quantum communication.
- Study quantum key distribution (QKD) protocols.
- Analyze quantum teleportation, entanglement swapping, and quantum repeaters.
- Evaluate quantum security principles and their advantages.
- Prepare students for designing secure communication protocols for future quantum networks.

Course Outcomes (COs)

CO Code	Description	Bloom's Level
CO1	Understand quantum communication concepts	Understand
CO2	Apply quantum entanglement to communication protocols	Apply
CO3	Analyze QKD protocols and teleportation mechanisms	Analyze
CO4	Evaluate security of quantum communication	Evaluate
CO5	Design quantum communication networks and protocols	Create

Syllabus Content

UNIT I – Introduction to Quantum Communication***(Cognitive Level: Understand)***

Classical communication vs quantum communication, No-cloning theorem and quantum information security, Qubits and qubit transmission channels, Quantum entanglement fundamentals, EPR paradox and Bell's inequalities, Quantum states and measurement, Role of superposition and measurement collapse, Overview of quantum internet and its architecture

UNIT II – Quantum Key Distribution (QKD) Protocols***(Cognitive Level: Apply)***

Classical cryptography limitations, BB84 protocol, B92 protocol, E91 entanglement-based protocol, Decoy-state QKD, Device-independent QKD, Practical implementation challenges in QKD, Experimental QKD systems (fiber, free-space, satellites)

UNIT III – Quantum Teleportation and Entanglement Distribution***(Cognitive Level: Analyze)***

Quantum teleportation protocol, Entanglement swapping, Quantum repeaters for long-distance communication, Error sources in quantum teleportation, Resource requirements for teleportation, Entanglement purification techniques, Bell state measurements, Applications of teleportation in distributed quantum computing

UNIT IV – Quantum Networks and Quantum Internet***(Cognitive Level: Evaluate)***

Architecture of quantum networks, Quantum routers and switching, Quantum memories and storage nodes, Distributed entanglement generation and management, Multiparty quantum communication Blind quantum computing, Performance metrics for quantum networks (fidelity, key rate), Challenges in large-scale quantum network deployment

UNIT V – Advanced Quantum Communication Protocols and Applications***(Cognitive Level: Create)***

Quantum secure direct communication, Quantum digital signatures, Position-based quantum cryptography, Quantum secret sharing, Post-quantum cryptography overview, Quantum cloud communication protocols, Building hybrid quantum-classical communication models, Future directions in quantum communication technology

Textbooks

1. M. Nielsen & I. Chuang – *Quantum Computation and Quantum Information*
2. Mark M. Wilde – *Quantum Information Theory*
3. Scarani – *Quantum Cryptography: A Primer*

Reference Books

1. VedranDunjko – *Introduction to Quantum Communication and Cryptography*
2. Norbert Lütkenhaus – *Practical Security in Quantum Key Distribution*
3. David McMahon – *Quantum Computing Explained*
4. Bouwmeester et al. – *The Physics of Quantum Information*

Online Courses & Resources

Platform	**Course Title**
edX	Quantum Cryptography (ETH Zurich)
Coursera	Quantum Communication (Delft University of Technology)
MIT OpenCourseWare	Quantum Information Science (MIT 6.443)
YouTube	Quantum Internet & Quantum Networking Tutorials
IBM Qiskit	Qiskit tutorials on quantum teleportation and QKD

(23A05M16) Introduction to Quantum Sensing

Course Objectives

- Introduce the principles of quantum sensing and metrology.
- Explain how quantum superposition and entanglement enhance measurement sensitivity.
- Study applications of quantum sensors across multiple domains.
- Analyze noise, decoherence, and quantum limits on measurement.
- Prepare students to design and analyze quantum-enhanced sensors.

Course Outcomes (COs)

CO Code	Description	Bloom's Level
CO1	Understand the basic principles of quantum sensing	Understand
CO2	Apply quantum superposition and entanglement to sensing	Apply
CO3	Analyze quantum sensor architectures	Analyze
CO4	Evaluate sensitivity and error limits in quantum measurements	Evaluate
CO5	Design quantum sensing systems for real-world applications	Create

Syllabus Content

UNIT I – Introduction to Quantum Sensing and Metrology ***(Cognitive Level: Understand)***

Classical vs quantum sensing, Precision limits: Standard Quantum Limit (SQL), Quantum metrology fundamentals, Heisenberg limit, Quantum phase estimation for precision measurements, Quantum non-demolition measurements, Quantum error correction in sensing, Importance of coherence and entanglement in sensors

UNIT II – Quantum Measurement Principles ***(Cognitive Level: Apply)***

Superposition and interference in measurement, Quantum Fisher information, Squeezed states for noise reduction, Photon counting and single-photon detectors, Spin-based measurements (NV centers, trapped ions), Ramsey interferometry, Quantum state tomography, Applications of quantum-enhanced interferometry

UNIT III – Quantum Sensor Technologies ***(Cognitive Level: Analyze)***

Atomic clocks (optical & microwave), Gravimeters and accelerometers, Magnetometers (SQUIDs, NV centers), Quantum gyroscopes, Quantum imaging & super-resolution microscopy, Quantum lidar and radar, Force and electric field sensing, Photonic quantum sensing systems

UNIT IV – Decoherence, Noise, and Error Mitigation in Quantum Sensing ***(Cognitive Level: Evaluate)***

Sources of decoherence in quantum sensors, Thermal noise and quantum noise sources, Quantum back-action, Squeezing and noise reduction techniques, Dynamical decoupling techniques, Noise spectroscopy for sensor calibration, Robust error mitigation protocols, Evaluating sensitivity vs noise tradeoffs

UNIT V – Advanced Applications and Future Quantum Sensing Systems ***(Cognitive Level: Create)***

Quantum sensing for biological and medical imaging, Navigation and positioning without GPS, Quantum-enhanced gravitational wave detection (LIGO), Quantum-enhanced environmental monitoring, Sensors for national defense and security, Space-based quantum sensors, Integrated quantum photonic sensing platforms, Design of hybrid quantum-classical sensor systems

Textbooks

1□. Christian L. Degen, F. Reinhard, P. Cappellaro – *Quantum Sensing* 2□. Giovannetti, Lloyd &Maccone – *Advances in Quantum Metrology* 3□. David Budker& Derek F. Jackson Kimball – *Optical Magnetometry*

Reference Books

1□. Kurt Jacobs – *Quantum Measurement Theory and its Applications*
2□. Helmut Rauch – *Neutron Interferometry*
3□. M. O. Scully & M. S. Zubairy – *Quantum Optics (Chapters on Metrology)*
4□. VlatkoVedral – *Introduction to Quantum Information Science*

Online Courses & Resources

Platform	**Course Title**
edX	Quantum Sensing & Metrology (LMU Munich)
Coursera	Quantum Optics and Sensing (University of Colorado Boulder)
MIT OpenCourseWare	Quantum Measurement and Sensing (MIT)
YouTube	Quantum Sensing Lectures
IBM Qiskit	Tutorials on Quantum Phase Estimation

(23A05M15P) Quantum Communication and Sensing Lab

Lab Objectives:

- Simulate and analyze quantum communication protocols.
- Implement quantum key distribution (QKD) and teleportation.
- Perform quantum sensing simulations for precision measurements.
- Evaluate sensor performance with noise and decoherence.
- Gain hands-on experience with quantum simulation tools.

List of Experiments (12 Experiments)

1. Simulation of Qubits and Bloch Sphere Visualization
2. Implementation of BB84 Quantum Key Distribution Protocol
3. Simulation of B92 and E91 QKD Protocols
4. Quantum Entanglement Generation and Bell Inequality Testing
5. Quantum Teleportation Protocol using Qiskit/Cirq
6. Simulation of Quantum Repeaters and Entanglement Swapping
7. Noise and DecoherenceModeling in Quantum Communication Channels
8. Ramsey Interferometry Simulation for Quantum Sensing
9. Implementation of NV CenterMagnetometry Simulation
10. Quantum Gravimeter and Accelerometer Simulation
11. Quantum Phase Estimation for High-Precision Metrology

Platforms & Tools:

- IBM Qiskit
- Google Cirq
- RigettiPyQuil
- Quantum Inspire
- MATLAB / Python with quantum libraries

(23A05M17P) QUANTUM DEVICES AND MATERIALS LAB

Lab Objectives:

- Simulate quantum devices and materials behavior.
- Explore quantum optics and solid-state quantum systems.
- Model quantum dots, superconductors, and photonic devices.
- Perform quantum simulation of condensed matter systems.
- Build foundational skills for quantum hardware understanding.

List of Experiments (12 Experiments)

1. Simulation of Single-Qubit Optical Devices
2. Modeling Quantum Dots and Energy Level Transitions
3. Simulation of Two-Level Atom and Rabi Oscillations
4. Quantum Harmonic Oscillator: Energy Levels Visualization
5. Spin-1/2 Systems and Magnetic Resonance Simulation
6. Superconducting Qubits Circuit Simulation
7. Josephson Junction Modeling for Quantum Circuits
8. Quantum Photonic Interferometer Simulation
9. Simulation of NV Centers in Diamond for Quantum Sensing
10. Solid-State Quantum Materials Simulation (Band Structures)
11. Modeling Quantum Light-Matter Interactions (Jaynes-Cummings Model)

Platforms & Tools:

- QuTiP (Quantum Toolbox in Python)
- Qiskit Nature / Qiskit Metal
- MATLAB Simulink
- COMSOL Multiphysics (for materials simulation)
- Silvaco TCAD (for device-level modeling)