

SREENIVASAINSTITUTE OF TECHNOLOGY AND MANAGEMENT STUDIES
(Autonomous)

Minor - QUANTUM TECHNOLOGIES - Offered by OPEN

S.No	Course Code	Course Title	Scheme of Instructions Hours per Week				Scheme of Examination Maximum Marks		
			L	T	P	C	I	E	Total
1	23MRQMT1	Foundations of Quantum Technologies	3	-	-	3	30	70	100
2	23MRQMT2	Solid State Physics for Quantum	3	-	-	3	30	70	100
3	23MRQMT3	Quantum Optics Prerequisites for Quantum Technologies	3	-	-	3	30	70	100
4	23MRQMT4	Introduction to Quantum	3	-	-	3	30	70	100
5	23MRQMT5	Introduction to Quantum Sensing	3	-	-	3	30	70	100
6	23MRQMT6	Quantum Communication and Sensing	-	-	3	1.5	30	70	100
7	23MRQMT7	Quantum Devices and Materials Lab	-	-	3	1.5	30	70	100

QUANTUM TECHNOLOGIES

23MRQMT1	Foundations of Quantum Technologies	L	T	P	C
		3	0	0	3

PRE-REQUISITES:

COURSE EDUCATIONAL 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.

UNIT I – Quantum Mechanics Foundations(Cognitive Level: Understand) (9)

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) (9)

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) (9)

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) (9)

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) (9)

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)

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Total Hours: 45

COURSE OUTCOMES:

On successful completion of the course- students will be able to		Bloom's Level
C01	Understand postulates of quantum mechanics for quantum technologies	Understand
C02	Apply linear algebra and Dirac notation to quantum state analysis	Apply
C03	Analyze superposition, entanglement, and measurement processes	Analyze
C04	Evaluate quantum systems through operators and probability amplitudes	Evaluate
C05	Create mathematical models for simple quantum systems	Create

TEXT BOOKS:

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. John Watrous – *The Theory of Quantum Information*
4. V.K. Krishnan – *Linear Algebra and its Applications to Quantum Computing*

REFERENCE WEBSITE:

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

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23MRQMT2	Solid State Physics for Quantum Technologies	L	T	P	C
		3	0	0	3

PRE-REQUISITES:

COURSE EDUCATIONAL 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.

UNIT I – Crystal Structure and Electronic Properties*(Cognitive Level: Understand) (9)*

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) (9)*

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) (9)*

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 (MoS₂, graphene)

UNIT IV – Lattice Vibrations and Phonon Interactions*(Cognitive Level: Evaluate) (9)*

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) (9)*

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

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COURSE OUTCOMES:

On successful completion of the course- students will be able to		Bloom's Level
C01	Understand crystal structures and band theory	Understand
C02	Apply knowledge of semiconductors, insulators, and conductors in quantum materials	Apply
C03	Analyze quantum confinement effects and low-dimensional systems	Analyze
C04	Evaluate defects, phonons, and interactions in solid-state systems	Evaluate
C05	Create models for quantum device material systems	Create

TEXT BOOKS:

- 1□. Charles Kittel – Introduction to Solid State Physics
2. 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

REFERENCE WEBSITE:

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

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23MRQMT3	Quantum Optics Prerequisites for Quantum Technologies	L	T	P	C
		3	0	0	3

PRE-REQUISITES:

COURSE EDUCATIONAL 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.

UNIT I – Classical and Quantum Description of Light (Cognitive Level: Understand) (9)

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) (9)

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) (9)

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) (9)

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) (9)

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

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COURSE OUTCOMES:

On successful completion of the course- students will be able to		Bloom's Level
C01	Understand quantum nature of light	Understand
C02	Apply Maxwell's equations to optical fields	Apply
C03	Analyze interaction of photons with matter	Analyze
C04	Evaluate coherence, squeezing, and quantum noise	Evaluate
C05	Create models for photonic quantum systems	Create

TEXT BOOKS:

- 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

REFERENCE WEBSITE:

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)

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23MRQMT4	Introduction to Quantum Communication	L	T	P	C
		3	0	0	3

PRE-REQUISITES:

COURSE EDUCATIONAL 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.

UNIT I – Introduction to Quantum Communication*(Cognitive Level: Understand) (9)*

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) (9)*

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) (9)*

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) (9)*

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) (9)*

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

COURSE OUTCOMES:

On successful completion of the course- students will be able to		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

TEXT BOOKS:

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. Vedran Dunjko – 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

REFERENCE WEBSITE:

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

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23MRQMT5	Introduction to Quantum Sensing	L	T	P	C
		3	0	0	3

PRE-REQUISITES:

COURSE EDUCATIONAL 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.

UNIT I – Introduction to Quantum Sensing and Metrology*(Cognitive Level: Understand) (9)*

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) (9)*

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) (9)*

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) (9)*

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) (9)*

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

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COURSE OUTCOMES:

On successful completion of the course- students will be able to		Bloom's Level
C01	Understand the basic principles of quantum sensing	Understand
C02	Apply quantum superposition and entanglement to sensing	Apply
C03	Analyze quantum sensor architectures	Analyze
C04	Evaluate sensitivity and error limits in quantum measurements	Evaluate
C05	Design quantum sensing systems for real-world applications	Create

TEXT BOOKS:

- 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□. Vlatko Vedral – Introduction to Quantum Information Science

REFERENCE WEBSITE:

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

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23MRQMT6	Quantum Communication and Sensing Lab	L	T	P	C
		-	-	3	1.5

PRE-REQUISITES: Nil.

COURSE EDUCATIONAL 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.

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 Decoherence Modeling in Quantum Communication Channels
8. Ramsey Interferometry Simulation for Quantum Sensing
9. Implementation of NV Center Magnetometry 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

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23MRQMT7	Quantum Devices and Materials Lab	L	T	P	C
		-	-	3	1.5

PRE-REQUISITES: Nil.

COURSE EDUCATIONAL 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.

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)

Course Outcomes:

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