

SIDDAGANGA INSTITUTE OF TECHNOLOGY, TUMAKURU-03

(An Autonomous Institution affiliated to Visvesvaraya Technological University, Belagavi,
Approved by AICTE, New Delhi)

QUANTUM PHYSICS AND APPLICATIONS

(For CSE/ISE/AIML/BT Branches)

Course Type: Integrated

Contact Hours/ Week:	3(L) + 2(P)	Credits:	4
Total Lecture Hours:	40 + 28	CIE Marks:	50
Course Code:	APS	SEE Marks:	50

Course objectives:

This course will enable students to:

1	Understand principles of quantum mechanics and its applications in quantum computing.
2	Analyze the electrical properties of metals/semiconductors using classical and quantum models.
3	Explore superconductivity principles, phenomena, and applications in quantum systems.
4	Explain light-matter interaction and the working of photonic devices like lasers & optical fibers.
5	Comprehend basic quantum computing concepts and predict simple quantum circuit outcomes.

UNIT I

Quantum Mechanics

de Broglie hypothesis of Matter Waves, de Broglie wavelength and derivation of expression by analogy, Phase velocity and Group velocity (only concept), Heisenberg's Uncertainty Principle and its application (Nonexistence of electron inside the nucleus-Non Relativistic), Time independent Schrodinger wave equation, Wave Function, Physical Significance of a wave function and Born Interpretation, Eigen functions and Eigen Values, Motion of a particle in a one dimensional potential well of infinite depth, Waveforms and Probabilities, Numerical Problems.

Prerequisites: Dual nature of matter.

Self-learning: deBroglie Hypothesis

8 Hours

UNIT II

Electrical Properties of Metals and Semiconductors

Assumptions of classical free electron theory, Failures of classical free electron theory, Mechanisms of electron scattering in solids, Matheissen's rule, Assumptions of Quantum Free

Electron Theory, Density of States (qualitative), Fermi Dirac statistics, Fermi Energy, Variation of Fermi Factor with Temperature and Energy, Types of semiconductors – Intrinsic and extrinsic semiconductor, Derivation of electron concentration in intrinsic semiconductor, Expression for intrinsic carrier concentration, Expression for electron and hole concentration in extrinsic semiconductor (qualitative), Fermi level for intrinsic and extrinsic semiconductor (qualitative), Hall effect in semiconductor, Expression for Hall coefficient and Hall voltage, Applications of Hall effect, Numerical Problems.

Prerequisites: Basics of electrical conductivity.

Self-learning: Success of QFET

8 Hours

UNIT III

Superconductivity

Introduction to superconductors, Temperature dependence of resistivity, Critical temperature, Critical field, Meissner effect, Critical current, Types of super conductors, Temperature dependence of critical field, BCS theory (qualitative), Limitations of BCS theory, High temperature superconductivity, Quantum tunneling (qualitative), Josephson Junction, Flux quantization, DC and AC SQUIDs (qualitative), Applications in quantum computing. Numerical Problems.

Prerequisites: Basics of electrical conductivity

Self-learning: Tunneling Effect

8 Hours

UNIT IV

Photonics

Basic properties of a LASER beam, Interaction of Radiation with Matter, Einstein's A and B Coefficients, Requisites of a laser system, Condition for Laser Action, Semiconductor diode Laser, Applications - Bar code scanner, Laser Printer. Numerical Problems.

Optical fiber - Principle and construction, Derivation of Numerical aperture, V-number, Number of modes, Attenuation and its mechanisms (qualitative). Application - Optical fiber communication, Numerical problems.

Prerequisites: Properties of light

Self-learning: Propagation Mechanism & TIR in optical fiber

8 Hours

UNIT V

Quantum Computing

Matrices - Row and Column matrices and their multiplication (Inner product), Conjugate and transpose of a matrix, Unitary matrix (U). Concepts of Hilbert's space, Dirac (Ket and Bra) notation, and Matrix form of wave function. Identity Operator, Determination of $|0\rangle$ and $|1\rangle$. Pauli Matrices and its operations on $|0\rangle$ and $|1\rangle$ states.

Introduction to Quantum Computing, Concept of Qubit - Bloch Sphere, properties, Difference between bit and qubit. Differences between classical & quantum computing. Moore's law - limitation of VLSI.

Single Qubit Gates: Quantum Not Gate, Pauli - Z Gate, Hadamard Gate, Two Qubit Gate: Controlled NOT Gate. Predicting the outputs of various combinations of single and two-qubit gates. Numerical Problems.

Prerequisites: Basics of Matrices, Classical computing, Concept of bit,

Self-learning: Moore's law

8 Hours

TEXT BOOKS

1	Satyendra Sharma and Jyotsna Sharma	Engineering Physics, Pearson, 2018.
2	S L Kakani, Shubra Kakani	Engineering Physics, CBS Publishers and Distributors Pvt. Ltd., 3rd Edition, 2020.
3	S. O. Pillai	Solid State Physics, New Age International, 2020.

REFERENCE BOOKS

1	H M Agarwal and R M Agarwal	Physics, Oscillations and Waves, Optics and Quantum Mechanics, Pearson, 2025
2	M. N. Avadhanulu, P. G. Kshirsagar and TVS Arun Murthy	A Text book of Engineering Physics, 11th revised Ed, S. Chand & Company Ltd, New Delhi, 2022
3	Mishra, P. K.	Superconductivity – Basics and Applications. Ane Books, 2009.
4	Parag K Lala	Quantum Computing, McGraw Hill, 2020.

e-Resources:

1. LASER : <https://www.youtube.com/watch?v=WgzynezPiyc>
2. Superconductivity : <https://www.youtube.com/watch?v=MT5Xl5ppn48>
3. Optical Fiber https://www.youtube.com/watch?v=N_kA8EpCUQo
4. Quantum Mechanics : <https://www.youtube.com/watch?v=p7bzE1E5PMY&t=136s>
5. Quantum Computing : <https://www.youtube.com/watch?v=jHoEjvuPoB8>
6. NPTEL Superconductivity: <https://archive.nptel.ac.in/courses/115/103/115103108/>
7. NPTEL Quantum Computing : <https://archive.nptel.ac.in/courses/115/101/115101092>
8. Virtual LAB : <https://www.vlab.co.in/participating-institute-amrita-vishwa-vidyapeetham>
9. Virtual LAB : <https://vlab.amrita.edu/index.php?sub=1&brch=189&sim=343&cnt=1>

LIST OF EXPERIMENTS

1. Determination of wavelength of LASER using Diffraction Grating.
2. Determination of acceptance angle and numerical aperture of the given Optical Fiber.
3. Study the Characteristics of a Photo-Diode and to determine the power responsivity
4. Determination of Planck's Constant using LEDs.
5. Verification of Stefan's law
6. Determination of Fermi Energy of Copper.
7. Determination of Energy gap of the given Semiconductor.
8. Black-Box Experiment (Identification of basic Electronic Components)
9. Resonance in LCR circuit.
10. Characteristics of a Bipolar Junction Transistor.
11. Determination of resistivity of a semiconductor by Four Probe Method.
12. Predicting the outputs of various combinations of single and two-qubit gates using QUIRK Quantum Simulator.
13. Predicting the outputs of various combinations of single and two-qubit gates using QUIRKIT.
14. Air-wedge / Newtons to study the interference by the division of amplitude.
15. Data Analysis using Spread Sheet.

Note: Any TEN experiments to be conducted from the above list by covering one a) Open Ended experiment with spreadsheet activity and b) Simulation.

Manual/Observation book:

1. Engineering Physics Lab Manual prepared by Faculty, Department of Physics, SIT.
--

Course Outcomes: Upon completion of this course the student will be able to:	
CO1	Apply the basics of quantum mechanics to show nonexistence of electrons in the nucleus and to solve the problems on de Broglie wavelength, uncertainty in position, energy, and particle in a potential well.
CO2	Apply the concepts of classical and quantum free electron theory to find Fermi factor , concentration of charge carriers, as well as Hall coefficient, Hall voltage for the semiconductor.
CO3	Apply the theory of superconductivity to find the critical temperature and critical field for superconducting state of the materials
CO4	Apply the theory of LASERs and optical fiber to solve the problems on condition of laser action, power of laser, numerical aperture and attenuation coefficient of optical fiber.
CO5	Apply the knowledge of quantum theory in quantum computation and able to find the output of quantum circuits having single and multiple qubit gates.

