Academic Year: 2025-26		
Course Title: Quantum Physics and Applications		
Course Code: P25PHCS102/202	**Semester: I/II**	**Scheme: P25**
Teaching hours/week(L:T:P): (3:0:0)	**CIE Marks: 50**	**CIE Weightage: 50%**
Credits: 03	**SEE Marks: 50**	**SEE Weightage: 50%**
Teaching hours of Pedagogy: 40 hours Theory	**Total: 100**	**Exam Hours: 3 Hrs**

Course Learning Objectives:

- To **study** the fundamental principles of quantum mechanics to analyze microscopic systems.
- To **recall** the origin of electrical conductivity in metals and semiconductors.
- To **learn** the properties of superconductors and their applications.
- To **understand**the concepts light–matter interaction and their role in laser-based technologies.
- To **explore**the idea of quantum information & quantum computing and their role in the development of quantum computing systems.

UNIT-I	Hrs: 08

Quantum Mechanics:de Broglie Hypothesis, Heisenberg's Uncertainty Principle and its application (Broadneing of Spectral Lines), Principle of Complementarity, Wave Function, Time independent Schrödinger wave equation (Derivation), Physical significance of a wave function and Born Interpretation, Expectation value and its physical significance, Eigen functions and Eigen values, Particle inside one dimensional infinite potential well, Role of higher dimensions (Qualitative), Waveforms and Probabilities, Particle inside a finite potential well and quantum tunneling, Numerical Problems.

Prerequisite: Physics principles like waves, particles, energy, momentum and atomic spectra

Self-Study Component: Particle inside a finite potential well and quantum tunneling

UNIT - II	Hrs: 08

Electrical Properties of Metals and Semiconductors: Failures of classical free electron theory, Mechanisms of electron scattering in solids, Matheissen's rule, Assumptions of Quantum Free Electron Theory, Density of States, Fermi Dirac statistics, Fermi Energy, Variation of Fermi Factor with Temperature and Energy, Expression for carrier concentration in a conductor, Mention of expression for electrical conductivity, Success of quantum free electron theory of metals, Derivation of electron concentration in an intrinsic semiconductor, Expression for electron and hole concentration in extrinsic semiconductor (Qualitative), Fermi level for intrinsic(with derivation) and extrinsic semiconductor (no derivation), Hall effect, Numerical Problems.

Prerequisite: Basicconcepts like energy bands and electrical conductivity in metals

Self-Study Component: Hole concentration in an extrinsic semiconductor	
UNIT - III	**Hrs: 08**
Superconductivity: Zero resistance state, Persitent current, Meissner effect, Critical temperature, Critical current (Silsbee Effect) – Derivation of expression of critical current for a cylindrical wire using ampere's law, Critical field, Formation of Cooper pairs - Mediation of phonons, Two-fluid model, BCS Theory - Phase coherent state, Limitations of BCS theory, Examples of systems with low and high electron-phonon coupling, Type-I and Type-II superconductors, Formation of Vortices, Explanation for upper critical field, Cooper pair Tunneling (Andreev reflection), Josephson junction, Flux quantization, DC and AC SQUID (Qualitative), Numerical Problems.	
Prerequisite: Solid state physics & fundamentals of electromagnetism	
Self-Study Component: Formation of vortices and DC and AC SQUID	
UNIT - IV	**Hrs: 08**
Photonics : Interaction of radiation with matter – Einstein's A and B coefficients and derivation of expression for energy density, Prerequisites for lasing actions, Types of LASER – Semiconductor diode LASER, Use of attenuators for single photon sources, Optical modulators - Pockel's effect, Kerr effect, Photodetectors – Single Photon Avalanche Diode, Superconducting Nanowire Single Photon Detector, Optical fiber, Derivation of Numerical aperture, V-number, Number of modes, losses in optical fiber, Mach-Zehnder interferometer, Numerical problems.	
Prerequisite: Concept of laser principles and wave propogation	
Self-Study Component: Mach-Zehnder interferometer	
UNIT - V	**Hrs: 08**
Quantum Computing: Moore's law - limitation of VLSI, Classical vs Quantum Computation, bit, Qubit and its properties, Bloch Sphere, Dirac notation, Brief discussion on types of qubit, Superconducting qubits, Harmonic oscillator (qualitative) – Need for anharmonicity, Charge qubit, Operators and Operations (Matrix form), Quantum Gates – Pauli Gates, Phase gate (S, T), Hadamard Gate, Two qubit gates – CNOT gate, Entangalment, Bell states, Predicting the outputs of various combinations of single and two-qubit gates, Numerical Problems.	
Prerequisite: Basics of Boolean logic and classical logic gates	
Self-Study Component: Harmonic oscillator	

Course Outcomes: At the end of the course students should be able to:
CO1:Explain core quantum concepts and their computational relevance.
CO2:Analyzeelectronic behavior in metals and semiconductors for key material properties.
CO3:Discuss superconductivity phenomena and their role in quantum systems.
CO4:Describe radiation–matter interaction and photonic device operation.
CO5:Summarize fundamentals of quantum computing and predict simple circuit outcomes.

Suggested Learning Resources:				
Text books:				
	Title	**Author**	**Year & Edition**	**Publisher**
1.	Engineering Physics	Satyendra Sharma and Jyotsna Sharma	2018	Pearson
2.	Engineering Physics	S L Kakani, Shubra Kakani	3rd Edition, 2020	CBS Publishers and Dis tributers Pvt. Ltd.
3	Solid State Physics	S O Pillai	2018	New Age Internationa
4	Quantum Computing,	Parag K Lala	2020	McGraw Hill
Reference Books:				
1.	LASERS and Non-Linear Optics	B B Loud	--	New Age International
2.	Concepts of Modern Physics	Beiser A	6th ed., 2002	McGraw-Hill Education
3.	Introduction to Quantum Mechanics	Griffiths D J	2nd or 3rd ed., 2018	Pearson
4.	Introduction to Superconductivity	TinkhamM	2nd ed., 2004	Dover Publications
5.	Superconductivity – Basics and Applications	Mishra P K	2009	Ane Books
6.	Quantum Computing	Vishal Sahani	2007	McGrawHill Education
7.	Fundamentals of Photonics	Saleh B E A & Teich M C	3rd ed., 2019	Wiley
8.	Quantum Computation and Quantum Information	Nielsen M A & Chuang I L	10th Anniversary ed.,2010	Cambridge University Press

Weblinks and Video Lectures (e-resources)
1. NPTEL – Quantum Mechanics I (IIT Madras): https://nptel.ac.in/courses/115106066. 2. NPTEL – Physics: Introductory Quantum Mechanics (NOC): https://archive.nptel.ac.in/courses/115/104/115104096. 3. Solid State Physics – NPTEL (IIT Madras) https://nptel.ac.in/courses/115106127. 4. A Brief Course on Superconductivity – NPTEL IIT Guwahati (Prof. SaurabhBasu) 5. Playlist Introduction Video: https://www.youtube.com/watch?v=SHoGV-sezNI. 6. Full playlist available via the YouTube channel description or archive link. 7. Concepts in Magnetism and Superconductivity – NOC (IIT Kharagpur)Series start (Lecture 1): https://digimat.in/nptel/courses/video/115105131/L01.html. 8. Introduction to Photonics – NPTEL (IIT Madras, Prof. Balaji Srinivasan) Lecture 03 to Lecture 12 cover: Direct video link (start Lecture 03): https://nptel.ac.in/courses/108106135/03. 9. Semiconductor Optoelectronics – NPTEL (IIT Delhi, Prof. M. R. Shenoy)Direct video link (start relevant lecture): https://nptel.ac.in/courses/108108174/05. 10. Lecture 04 – Quantum Computing Basics: https://www.youtube.com/watch?v=-fttE1SzpD8. 11. . Lecture 08 – Quantum Gates and Circuits Part 1:https://www.youtube.com/watch?v=nGPr1QM_XrY.

Teaching Learning Process:	
1. Chalk and talk	2. Short Animations and Videos
3.Experimential Learning	4. Active based Learning
5. Hybrid Learning	6. Simulations and Interactive Simulations
7. ICT Based Learning	8. Self Learning using AI Tools

Active Based Learning (Suggested Activities in Class)/Practical Based Learning
http://nptel.ac.in https://swayam.gov.in https://virtuallabs.merlot.org/vl_physics.html https://phet.colorado.edu https://www.myphysicslab.com

Course Articulation Matrix of Quantum Physics and Applications

COs / POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	2	-	-	2	-	-	-	-	-	2
CO2	3	3	2	-	2	-	-	-	-	-	2
CO3	3	2	-	2	2	-	-	-	-	-	2
CO4	3	2	-	2	3	-	-	-	-	-	2
CO5	3	2	2	-	3	-	-	-	-	-	2

<table>
<tr><td colspan="3" align="center">Academic Year: 2025-26</td></tr>
<tr><td colspan="3" align="center">CourseTitle: Quantum Physics and Applications Laboratory
Semester: I/II</td></tr>
<tr><td>Course Code:</td><td>P25PHCSL107/207</td><td>Credit: 01</td></tr>
<tr><td>Teaching hours/week(L:T:P):</td><td>0:0:2</td><td>CIE Marks: 50</td></tr>
<tr><td>Teaching hours of Pedagogy:</td><td>10-12 Lab slots</td><td>SEE Marks: 50</td></tr>
<tr><td colspan="3">Course Learning Objectives:
• Identify the principles of quantum physics to perform and analyze laboratory experiments related to Engineering field.
• Setup or construct the circuit to perform experiments related to Engineeeringapplicatons.
• Analyzethe knowledge of mathematical sciences to calculate experimental result comparing with theory related to Engineering field.</td></tr>
<tr><td colspan="2" align="center">PART–A: Fixed Set of Experiments</td><td>24Hours</td></tr>
<tr><td colspan="3">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/ Verification of Inverse Square Law of Light
4. Determination of Planck's Constant using LEDs/Black-Body.
5. Determination of Fermi Energy of Copper.
6. Determination of Energy gap of the given Semiconductor.
7. Black-Box Experiment(Identification of basic Electronic Components).
8. Resonance in LCR circuit and determination of coefficient of self induction.
9. Study the I-V Characteristics of a Bipolar Junction Transistor and hence determine α & β.
10. Determination of resistivity of a semiconductor by Four Probe Method.
11. Predicting the outputs of various combinations of single and two-qubit gates using QUIRK Quan-tum Simulator. a) https://www.quirk-e.dev/ b) https://algassert.com/quirk
12. Predicting the outputs of various combinations of single and two-qubit gates using QISKIT.
13. Air-wedge / Newtons to study the interference by the division of amplitude.
14. Experimental Data Analysis using Spread Sheet.</td></tr>
</table>

Course Outcomes: On completion of this course, students should be able to:
CO1: Apply the fundamental concepts of physics by performing laboratory experiments using electronic components and circuits.
CO2: Analyze and interpret experimental data, calculate errors and compare results with theoretical predictions to validate physical laws and engineering applications.
CO3: Demonstrate the use of simulation tools such as PHET, Spreadsheets and Tracker to model, visualize and investigate physical phenomena for engineering problem solving.

Suggested Learning Resources:				
Text books:				
	Title	**Author**	**Year & Edition**	**Publisher**
1.	Engineering Physics Practical	V Rajendran	Latest Edition	Tata McGraw Hill
2.	Practical Physics	S L Gupta, V Kumar	Latest Edition	Pragati Prakashan
Reference Books:				
1.	Applied Physics Laboratory Manual	R Arora	Latest Edition	S. Chand & Co.,
2.	Laboratory Experiments in Engineering Physics	D Chattopadhyay, P C Rakshit	Latest Edition	New Central Book Agency
3.	Learn Quantum Computation using Qiskit (Lab-Oriented Text)	H Abraham et al. (IBM Research)	2019, Open Access	Qiskit Textbook Project
4.	Spreadsheet Applications in Science Education	Thomas J Quirk	2nd Edition, 2015	Springer

Course Articulation Matrix of Quantum Physics and Applications Laboratory											
COs / POs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**
CO1	3	2	-	-	-	-	-	-	-	-	-
CO2	2	3	-	2	-	-	-	-	2	-	-
CO3	1	2	-	-	3	-	-	-	1	-	2