SIDDAGANGA INSTITUTE OF TECHNOLOGY, TUMAKURU-3
(An Autonomous Institution affiliated to Visvesvaraya Technological University, Belagavi, Approved by AICTE, New Delhi)

QUANTUM PHYSICS AND ELECTRONICS SENSORS

(For EC/EI/ET Branches)

Course Type: Integrated

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

Course objectives:
This course will enable students to:

1	Study the principles of quantum mechanics.
2	Analyze the electrical properties of metals and semiconductors using classical and quantum models.
3	Explore superconductivity principles, phenomena, and their applications
4	Explain light-matter interaction and the working of photonic devices like lasers & optical fibers.
5	Demonstrate the principles, characteristics, and applications of semiconductor devices.

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), Wave Function, Time independent Schrodinger wave equation, 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: Types of semiconductor, 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 superconductors, Temperature dependence of critical field, BCS theory (qualitative), Limitations of BCS theory, High temperature superconductivity, Quantum tunneling (qualitative), Josephson Junction, Flux quantization, DC SQUIDs (qualitative), Applications - superconducting magnet, Maglev Vehicle, Numerical Problems.

Prerequisites: Basics of electrical conductivity
Self-learning: Tunneling Effect

8 Hours

UNIT IV

Photonics

Laser: 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

Semiconductor devices and Sensors

Formation of bands due to splitting of energy levels at equilibrium inter-nuclear distance - silicon, Direct and indirect band gap, LED, Photo-Diode, Photo Transistor, Light dependent resistor, Sensing mechanisms, Piezoelectric Sensors, Metal Oxide Semiconductor (MOS)

sensors, Hall sensor, Superconducting Nanowire Single Photon Detector, Numerical Problems. **Prerequisites:** Basics of semiconductors **Self-learning:** p-n junction and its V-I characteristics
8 Hours

TEXT BOOKS		
1	M. N. Avadhanulu, P. G. Kshirsagar and TVS Arun Murthy	A Text book of Engineering Physics, 11th Ed, S. Chand & Company Ltd, New Delhi, 2022
2	S L Kakani, Shubra Kakani	Engineering Physics, 3rd Edition, CBS Publishers and Distributers Pvt. Ltd., 2020.
3	Satyendra Sharma and Jyotsna Sharma	Engineering Physics, Pearson, 2018.

REFERENCE BOOKS		
1	H M Agarwal and R M Agarwal	Physics, Oscillations and Waves, Optics and Quantum Mechanics, Pearson, 2025
2	S Mani Naidu	Engineering Physics, Pearson, Fourteenth Impression, 2024.
3	Mishra, P. K.	Superconductivity – Basics and Applications. Ane Books, 2009.
4	S. O. Pillai	Solid State Physics, 8th Ed- New Age International Publishers-2018.
5	B L Theraja	Basic Electronics, Multi-Colour Edition, S Chand, 2006

Web links and Video Lectures (e-Resources):

1. NPTEL – Quantum Mechanics I (IIT Madras): https://nptel.ac.in/courses/115106066
2. Solid State Physics – NPTEL (IIT Madras) https://nptel.ac.in/courses/115106127
3. A Brief Course on Superconductivity – NPTEL IIT Guwahati (Prof. Saurabh Basu)
4. Playlist Introduction Video: https://www.youtube.com/watch?v=SHoGV-sezNI, Full playlist available via the YouTube channel description or archive link.
5. Concepts in Magnetism and Superconductivity – NOC (IIT Kharagpur)Series start (Lecture 1): https://digimat.in/nptel/courses/video/115105131/L01.html
6. 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
7. Semiconductor Optoelectronics – NPTEL (IIT Delhi, Prof. M. R. Shenoy)Direct video link (start relevant lecture): https://nptel.ac.in/courses/108108174/05
8. Sensors and Actuators – NPTEL (IISc Bangalore, Prof. Hardik J. Pandya) Lecture 1 – Introduction to Sensors, Transducers & Actuators, incl. Hall, RTDs, Thermistors https://digimat.in/nptel/courses/video/108108147/L01.html
9. Smart Sensors – NPTEL Lecture 34 – Covers various sensors including gas, pressure, MOS sensors, photodetectors like SNSPD https://www.youtube.com/watch?v=oRydUfgMdgA
10. Lecture 32 – Superconducting Qubits (includes Charge Qubit / Cooper-Pair Box) https://www.youtube.com/watch?v=iYo8ALJ-Mls

LIST OF EXPERIMENTS

1. Determination of the wavelength of LASER using Diffraction Grating.
2. Determination of acceptance angle and numerical aperture of the given Optical Fiber.
3. Determination of dielectric constant of the material of capacitor by Charging and Discharging method.
4. Study the Characteristics of a Photo-Diode and to determine the power responsivity
5. Determination of Plank's Constant using LEDs.
6. Determination of Fermi Energy of Copper.
7. Interference by the division of amplitude (Air-wedge/Newton's Rings)
8. Black-Box Experiment
9. Construction and Analyzing of Electronic circuits (Expeyes Simulator / circuit lab)
10. Verification of the Inverse Square Law of Intensity of Light.
11. I-V Characteristics of a Bipolar Junction Transistor.
12. I-V Characteristics of a Zener diode.
13. Resonance in LCR circuit
14. Energy Gap of a Semiconductor
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/Circuit lab.

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 the 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 quantum free electron theory to find Fermi factor and concentration of charge carriers, Hall coefficient, Hall voltage for the semiconductor.
CO3	Apply the theory of superconductivity to find the critical temperature and critical field for the superconducting state of the materials.
CO4	Apply the theory of LASERs and optical fiber to solve the problems on the condition of laser action, power of laser, numerical aperture and attenuation coefficient of optical fiber.
CO5	Analyze the various semiconductor devices for electronic and photonic applications.

Course Articulation Matrix

		POs											PSOs	
		1	2	3	4	5	6	7	8	9	10	11	1	2
COs	CO1	3	3	-	-	-	-	-	-	-	-	-	-	-
	CO2	3	2	-	-	-	-	-	-	-	-	-	-	-
	CO3	3	2	-	-	-	-	-	-	-	-	-	-	-
	CO4	2	2	-	-	-	-	-	-	-	-	-	-	-
	CO5	3	3	-	-	-	-	-	-	-	-	-	-	-