QUANTUM PHYSICS AND ELECTRONIC SENSORS		Semester	1/2
Course Code	1BPHEC102/202	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	3:0:2:0	SEE Marks	50
Total Hours of Pedagogy (Theory and Lab hours)	40	Total Marks	100
Credits	40 hours theory and 10-12 hours of practical sessions	Exam Hours	3 hours
Examination type (SEE)	DESCRIPTIVE		

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. Apply fundamental principles of quantum mechanics to analyze microscopic physical systems and predict quantized energy states and tunneling phenomena.
2. Analyze electrical conduction mechanisms in metals and semiconductors using classical and quantum models, and interpret carrier concentration and Fermi energy calculations.
3. Evaluate superconductivity phenomena including Meissner effect, Cooper pair formation, and Josephson junction behavior for advanced material applications.
4. Describe light-matter interaction, laser operations, optical modulators, and photonic devices to illustrate principles of photonics in sensor technologies.
5. Demonstrate the principles, characteristics, and applications of semiconductor and optical devices, sensors, and transducers used in electronic and photonic systems.

Module-1

Quantum Physics:

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.

Text Book : 1 and 2 Number of Hours: 8

Module-2

Electrical Properties of Metals and Semiconductors

Failures of classical free electron theory, Mechanisms of electron scattering in solids, Matheissen's rule, Assumptions of auantum free electron theory, Density of states, Fermi Dirac statistics, Fermi energy, Variation of Fermi factor with temperature and energy, Expression for carrier concentration, Derivation of electron concentration in an intrinsic semiconductor, Expression for electron and hole concentration in extrinsic semiconductor, Fermi level for intrinsic (with derivation) and extrinsic semiconductor (no derivation), Hall effect, Numerical Problems.

Text Books : 1, 3 Reference Books : 2, 3 Number of

Module-3

Superconductivity

Zero resistance state, Persitent current, Meissner effect, Critical temperature, Critical current (Silsbee Effect) – Derivation 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, Josephson junction, Flux quantization, DC and AC SQUID, Charge Qubit, Numerical Problems.

Text Books: 1, 2, Reference Book: 4, 8 Number of Hours:8

Module-4

Photonics :

Interaction of radiation with matter – Einstein's A and B coefficients, 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 – Photomultiplier tube, Single Photon Avalanche Diode, Optical fiber, Derivation of Numerical aperture, V-number, Number of modes, losses in optical fiber, Mach-Zehnder interferometer, Numerical problems.

Text Books: 1, 2, Reference Book: 7 Number of Hours:8

Module-5

Semiconductor devices and Sensors

Direct and indirect band gap, Band gap engineering, Zener Diode, LED, PhotoDiode, Photo Transistor, Light dependent resistor, Resistance temperature detectors (high, medium, low), Sensing mechanisms, Piezo electric Sensors, Metal Oxide Semiconductor (MOS) sensors, Hall sensor, Superconducting Nanowire Single Photon Detector, Numerical Problems.

Text Book : 4, Reference Book : 1 Number of Hours:8

PRACTICAL COMPONENTS OF IPCC

PART – A: FIXED SET 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. Determination of resistivity of a semiconductor by Four Probe Method
4. Determination of dielectric constant of the material of capacitor by Charging and Discharging method.
5. Study the Characteristics of a Photo-Diode and to determine the power responsivity / Verification of inverse square law of light.
6. Determination of Plank's Constant using LEDs.
7. Determination of Fermi Energy of Copper.
8. Interference by the division of amplitude (Air-wedge/Newton's Rings)
9. Black-Box Experiment
10. Construction and Analyzing Electronic circuits (Expeyes Simulator / circuitlab)
11. Verification of Inverse Square Law of Intensity of Light.
12. I-V Characteristics of a Bipolar Junction Transistor.
13. Resonance in LCR circuit
14. Energy Gap of a Semiconductor

(One Simulation Experiment is compulsory and must be conducted either in the Computer Laboratory for the entire batch or using dedicated systems within the Physics Laboratory as part of the experimental cycles.)

PART – B: OPEN ENDED EXPERIMENTS

Open-ended experiments are a type of laboratory activity where the outcome is not predetermined and students are given the freedom to explore, design, and conduct the experiment based on the problem statements as per the concepts defined by the course coordinator. It encourages creativity, critical thinking, and inquiry-based learning.

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. **Engineering Physics, Satyendra Sharma and Jyotsna Sharma, Pearson, 2018.**
2. **Engineering Physics, S L Kakani, Shubra Kakani, 3rd Edition, 2020, CBS Publishers and Distributers Pvt. Ltd.**
3. **Solid State Physics, S. O. Pillai, New Age International**
4. **Basic Electronics, B L Theraja, Multi-color Edition, S Chand, 2006**

Reference books / Manuals:

1. **Engineering Physics , S Mani Naidu, Pearson, Fourteenth Impression, 2024.**
2. **Beiser, A. (2002). Concepts of Modern Physics (6th ed.). McGraw-Hill Education..**
3. **Griffiths, D. J. (2018). Introduction to Quantum Mechanics (2nd or 3rd ed.). Pearson.**
4. **Tinkham, M. (2004). Introduction to Superconductivity (2nd ed.). Dover Publications.**
5. **Mishra, P. K. (2009). Superconductivity – Basics and Applications. Ane Books.**
6. **Ghatak, A., & Thyagarajan, K. (2005). Optical Electronics. Oxford University Press.**
7. **Saleh, B. E. A., & Teich, M. C. (2019). Fundamentals of Photonics (3rd ed.). Wiley**
8. **Nielsen, M. A., & Chuang, I. L. (2010). Quantum Computation and Quantum Information (10th Anniversary ed.). Cambridge University Press.**

Web links 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. Saurabh Basu)
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. 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
11. Smart Sensors – NPTEL Lecture 34 – Covers various sensors including gas, pressure, MOS sensors, photodetectors like SNSPD https://www.youtube.com/watch?v=oRydUfgMdgA
12. Lecture 32 – Superconducting Qubits (includes Charge Qubit / Cooper-Pair Box) https://www.youtube.com/watch?v=iYo8ALJ-Mls

Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. .Self Learning using AI Tools
2. Activity Based Learning
3. Gamification of Activities
4. Short Animations and Videos
5. Models and Working Models
6. Simulations and Interactive Simulations
7. Experiential Learning
8. Flipped Class Learning
9. Hybrid Learning
10. ICT Based Learning

Assessment Structure:
The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).
The CIE Theory component will be30 marks and CIE Practical component will be 20 marks.

The CIE Theory component consists of IA tests for 25 marks and Continuous Comprehensive Assessments (CCA) for 5 marks. The CIE Practical component for continuous assessments will be for 15 marks through rubrics and for lab tests will be for 5 marks.

- To qualify and become eligible to appear for SEE, in the **CIE theory component**, a student must score at least **40% of 30 marks**, i.e., **12 marks**.
- To qualify and become eligible to appear for SEE, in the **CIE Practical component**, a student must secure **a minimum of 40% of 20 marks**, i.e., **08 marks**.
- To pass the **SEE**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks**.
- A student is deemed to have **successfully completed the course** if the **combined total of CIE (and SEE is at least 40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA):

CCA will be conducted for a total of 5 marks. It is recommended to include any one learning activity aimed at enhancing the holistic development of students. This activity should align with course objectives and promote higher-order thinking and application-based learning.

Learning Activity -1: (Marks- 5)

CIE Practical component:

The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. The summation of all the experiments marks to be scaled down to 15 marks.

The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and scaled down to 5 marks. For laboratory test, the student is required to conduct one experiment each from both Part A and Part B.

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator 1 (CO1 - PO1, PO2, PO5, PO11)	Explains quantum mechanical principles and quantized energy levels with clarity and depth	Explains most concepts accurately with minor gaps	Shows basic understanding but lacks connection to application	Misunderstands or inconsistently applies key quantum principles	Fails to explain or apply core quantum mechanics concepts
Performance Indicator 2 (CO2 - PO1, PO2, PO3, PO5, PO11)	Analyzes conduction models and calculates carrier concentration and Fermi levels accurately	Good interpretation with small conceptual errors	Partial understanding with simple calculation attempts	Inaccurate analysis or incomplete application of models	Unable to perform conduction analysis or interpret results
Performance Indicator 3 (CO3 - PO1, PO2, PO4, PO5, PO11)	Evaluates superconductivity and Josephson junction behavior with clear reasoning and examples	Explains effects with fair understanding and application	Recognizes phenomena but lacks detailed reasoning	Minimal interpretation or misapplication of principles	Fails to identify superconducting phenomena or applications
Performance Indicator 4 (CO4 - PO1, PO2, PO4, PO5, PO11)	Thoroughly investigates light-matter interaction and evaluates photonic devices effectively	Good device interpretation and physical explanation	Basic knowledge of devices with limited contextual clarity	Weak or inconsistent understanding of photonic systems	Lacks or misrepresents device functionality and interaction concepts
Performance Indicator 5 (CO5 - PO1, PO2, PO3, PO5, PO11)	Demonstrates strong understanding and correct use of sensors and transducers in electronic systems	Applies concepts correctly with minor gaps in logic or selection	Recognizes device function but lacks depth in analysis	Incorrect application or unclear explanation of sensors	Fails to identify or describe devices or their functions

Rubrics for CIE – Continuous assessment:

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator 1 (CO1 - PO1, PO2, PO5, PO11)	Explains quantum mechanical principles and quantized energy levels with clarity and depth	Explains most concepts accurately with minor gaps	Shows basic understanding but lacks connection to application	Misunderstands or inconsistently applies key quantum principles	Fails to explain or apply core quantum mechanics concepts

Performance Indicator 2 (CO2 - PO1, PO2, PO3, PO5, PO11)	Analyzes conduction models and calculates carrier concentration and Fermi levels accurately	Good interpretation with small conceptual errors	Partial understanding with simple calculation attempts	Inaccurate analysis or incomplete application of models	Unable to perform conduction analysis or interpret results
Performance Indicator 3 (CO3 - PO1, PO2, PO4, PO5, PO11)	Evaluates superconductivity and Josephson junction behavior with clear reasoning and examples	Explains effects with fair understanding and application	Recognizes phenomena but lacks detailed reasoning	Minimal interpretation or misapplication of principles	Fails to identify superconducting phenomena or applications
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Performance Indicator 5 (CO5 - PO1, PO2, PO3, PO5, PO11)	Demonstrates strong understanding and correct use of sensors and transducers in electronic systems	Applies concepts correctly with minor gaps in logic or selection	Recognizes device function but lacks depth in analysis	Incorrect application or unclear explanation of sensors	Fails to identify or describe devices or their functions

Rubrics for SEE / CIE Test:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator 1 (CO1 - PO1, PO2, PO5, PO11)	Explains quantum mechanical principles and quantized energy levels with clarity and depth	Explains most concepts accurately with minor gaps	Shows basic understanding but lacks connection to application	Misunderstands or inconsistently applies key quantum principles	Fails to explain or apply core quantum mechanics concepts
Performance Indicator 2 (CO2 - PO1, PO2, PO3, PO5, PO11)	Analyzes conduction models and calculates carrier concentration and Fermi levels accurately	Good interpretation with small conceptual errors	Partial understanding with simple calculation attempts	Inaccurate analysis or incomplete application of models	Unable to perform conduction analysis or interpret results
Performance Indicator 3 (CO3 - PO1, PO2, PO4, PO5, PO11)	Evaluates superconductivity and Josephson junction behavior with clear reasoning and examples	Explains effects with fair understanding and application	Recognizes phenomena but lacks detailed reasoning	Minimal interpretation or misapplication of principles	Fails to identify superconducting phenomena or applications

Performance Indicator 4 (CO4 - PO1, PO2, PO4, PO5, PO11)	Thoroughly investigates light-matter interaction and evaluates photonic devices effectively	Good device interpretation and physical explanation	Basic knowledge of devices with limited contextual clarity	Weak or inconsistent understanding of photonic systems	Lacks or misrepresents device functionality and interaction concepts
Performance Indicator 5 (CO5 - PO1, PO2, PO3, PO5, PO11)	Demonstrates strong understanding and correct use of sensors and transducers in electronic systems	Applies concepts correctly with minor gaps in logic or selection	Recognizes device function but lacks depth in analysis	Incorrect application or unclear explanation of sensors	Fails to identify or describe devices or their functions

Suggested rubrics for Practical continuous assessment:

Performance Indicators	Excellent	Very Good	Good	Satisfactory
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
Implementation (8) (PO3 & PO7)	Student is capable of implementing the design with best suitable algorithm considering optimal solution. (7-8)	Student is capable of implementing the design with best suitable algorithm and should be capable of explaining it (5-6)	Student is capable of implementing the design with proper explanation. (3-4)	Student is capable of implementing the design. (1-2)
Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result with proper analysis. (5)	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyze the output (3)	Student will be able to run the program but not able to analyze the output (1-2)
Demonstration (8) (PO8)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

	smooth. (7-8)			

Note: Can add Engineering & IT tool usage based on the nature of the course

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play