Physics of Electrical Engineering Materials		Semester	I/II
Course Code	**1BPHEE102/102**	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)	64	Total Marks	100
Credits	4	Exam Hours	3
Examination type (SEE)	**Descriptive**		

Course outcome (Course Skill Set)

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

1. Illustrate dielectric and magnetic properties of materials and apply them in electrical components like transformers, capacitors, and magnetic switches.
2. Summarize thermoelectric phenomena, device construction, and identify suitable materials and applications for energy conversion.
3. Discuss electrical transport mechanisms in metals and semiconductors using classical and quantum models, and perform relevant calculations.
4. Explain superconducting principles, distinguish between types of superconductors, and explain their physical properties and technological uses.
5. Describe the principles, properties, and applications of rare earth, ceramic, and smart materials in energy systems.

Module-1

Dielectric and Magnetic Materials:

Dielectrics :

Introduction, Electrical Polarization Mechanisms, Internal fields in solids (qualitative), Clausius-Mossotti relation (Derivation) and its implications, Properties and Frequency dependence of Dielectric constant, Dielectric loss, Solid, Liquid and Gaseous dielectrics. Application of dielectrics in Capacitors, Transformers (Oils), SF6 in High Voltage application, Numerical Problems.

Magnetic material :

Classification of magnetic materials, Weiss Molecular field theory of ferromagnetism(Qualitative), Importance of Curie Temperature, Ferromagnetic Hysteresis and Explanation using Domain theory, Energy loss, Hard and soft ferromagnetic materials and Applications, Transformer Cores, Armature, Inductors and chokes, Permanent Magnets, Numerical Problems

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

Module-2

Thermoelectric materials and devices:

Thermo emf and thermo current, Seebeck effect, Peltier effect, Seebeck and Peltier coefficients, figure of merit (Mention Expression), laws of thermoelectricity. Expression for thermo emf in terms of T1 and T2, Thermo couples, thermopile, Construction and Working of Thermoelectric generators (TEG) and Thermoelectric coolers (TEC), low, mid and high temperature thermoelectric materials, Applications: Exhaust of Automobiles, Refrigerator, Space Program (Radioisotope Thermoelectric Generator), Numerical Problems

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

Module-3

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, 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 : 1,2 , Reference Book: 1, 4 Number of Hours:

Module-4
Superconductivity Zero resistance state, Persistent 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, Type-I and Type-II superconductors, High Tc superconductors, Formation of Vortices, Explanation for upper critical field, Josephson junction, Flux quantization, DC Squid, Superconducting Magenet, MAGLEV, Numerical Problems. Text Books :1, 3, Reference Book:1, 2 Number of Hours: 8
Module-5
Electrical Engineering Materials Rare earth materials, Role in energy systems, Electrical & Magnetic phase diagram, Examples & high magnetic field applications, Ceramics: Types, Materials, Applications, Electrostriction, Strain proportional to square of the electric field, Comparison with piezoelectric effect, Materials, Applications, Electrorheological (ER) materials, Principle, Viscosity changes under applied electric field, ER Fluids, Applications, Magnetorheological (MR) materials, Principle, Magnetic field-induced change in viscosity, MR Fluids, Applications. Numerical Problems Text Books :4, Reference Book: 5 Number of Hours: 8

PRACTICAL COMPONENTS OF IPCC

PART – A: FIXED SET OF EXPERIMENTS

1. Determination of dielectric constant of the material of capacitor by charging and discharging method.
2. Determination of Magnetic Flux Density at any point along the axis of a circular coil.
3. Determination of resistivity of a semiconductor by Four Probe Method.
4. Study the Characteristics of the given Photo-Diode and determine the power responsivity.
5. Study the frequency response of Series & Parallel LCR circuits.
6. Determination of Fermi Energy of Copper.
7. Tracing of B-H Curve for a ferromagnetic material.
8. Maxwell's / Wheatstone bridge circuits – Determination of unknown value of inductance / resistance.
9. Experiment on Thermo-emf / Peltier Module.
10. Black-Box Experiment Black-Box Experiment (Identification of basic Electronic/Electrical Components)
11. Determine the Energy Gap of the given Semiconductor.
12. To study the operation of a multimeter and use it for measuring **resistance, current, voltage**, and for testing **diodes, transistors, and continuity in conductors**.
13. Experimental Data Analysis using Spread Sheets.
14. Construction and Analyzing Electronic circuits using one of the following
    1. Expeyes : https://expeyes.in/
    2. Circuit Lab : https://www.circuitlab.com/
    3. Multisim : https://www.multisim.com/
    4. DCAClab : https://dcaclab.com/
    5. Falstad : https://www.falstad.com/circuit/

Note :

1. At least ten laboratory experiments must be conducted.
2. Minimum one simulation experiment is mandatory and should be conducted either in the computer lab for the entire batch or on dedicated systems in the physics lab.

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

Text books:

1. Solid State Physics-S O Pillai, 8th Ed- New Age International Publishers-2018.
2. Engineering Physics, Satyendra Sharma and Jyotsna Sharma, Pearson, 2018.
3. A Text book of Engineering Physics by M.N. Avadhanulu, P G. Kshirsagar, S Chand, 2014, Revised Edition.
4. Smart Materials and Structures, M. V. Gandhi and B. S. Thompson , Chapman & Hall

Reference books / Manuals:

1. Engineering Physics, S L Kakani, Shubra Kakani, 3rd Edition, 2020, CBS Publishers and Distributers Pvt. Ltd., 2018
2. Tinkham, M. (2004). Introduction to Superconductivity (2nd ed.). Dover Publications.
3. Engineering Physics, Wiley Precise Text Books Series, Wiley,2014
4. Engineering Physics-Gaur and Gupta-Dhanpat Rai Publications-2017.
5. Electrical Engineering Materials, R. K. Shukla, Tata McGraw-Hill Education, India , 2017 reprint edition.

Web links and Video Lectures (e-Resources):

1. Mod-02 Lec-20: Dielectrics – Prof. D. K. Ghosh, IIT Bombay
   https://www.youtube.com/watch?v=P9VyW2wq9ZE
2. Mod-01 Lec-16: Dielectric (Insulating) Solids – Prof. G. Rangarajan, IIT Madras
   https://www.youtube.com/watch?v=etjZmdmrjSU
3. Lecture 41: Thermoelectric Generators – Functioning and Applications
   https://www.youtube.com/watch?v=G9NgoxHMPwk
4. NPTEL course: Solid State Physics – Prof. A.K. Raychaudhuri, IIT Kharagpur
   Course link: https://archive.nptel.ac.in/courses/115/105/115105099
5. Mod-01 Lec-27: Superconductivity – Perfect Conductivity & Diamagnetism – Prof. G. Rangarajan, IIT Madras https://www.youtube.com/watch?v=GglT1RoBPzg
6. Lecture 01: PMMC Instrument – https://www.youtube.com/watch?v=n1MinLtvnPY
7. Lecture 02: Electrodynamic / Moving Iron Instruments –
   https://www.youtube.com/watch?v=n1MinLtvnPY&list=PLbRMhDVUMngcoKrA4sH-zvbNVSE6IpEio&index=2
8. Lecture 03: Measurement Systems Characteristics – https://www.youtube.com/watch?v=Hlvbr5DCEfM
9. Lecture 05: Moving Iron Instruments – https://www.youtube.com/watch?v=TgGMqVPsaK0
10. Lecture 23: Error Calculation & Uncertainty – https://www.youtube.com/watch?v=ZpYGQQAix0E
11. Electrical Measurement course Prof Avishek Chatterjee IIT Kharagpur :
    https://www.youtube.com/playlist?list=PLbRMhDVUMngcoKrA4sH-zvbNVSE6IpEio

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 (IPCC): (Circular-Ref.: VTU/BGM/IPCC 2025/3748, DATED: 24TH Oct 2025)

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 be **25 marks** and CIE Practical component will be **25 marks**.

The CIE Theory component consists of IA tests for **25 marks**. The CIE Practical component for continuous assessments will be for **15 marks** through rubrics and for lab Internal Assessment will be conducted for **10 marks** through rubrics.

- To qualify and become eligible to appear for SEE, in the **CIE theory component**, a student must score at least **40% of 25 marks**, i.e., **10 marks**.
- To qualify and become eligible to appear for SEE, in the **CIE Practical component**, a student must secure **a minimum of 40% of 25marks**, i.e., **10marks.**
- 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 **completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

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, PO3, PO12)	Explains dielectric and magnetic properties and their role in real components like transformers and capacitors with clarity	Good explanation with minor application errors	Basic understanding of properties but unclear application	Limited or incorrect linkage of concepts to components	Fails to explain or apply dielectric and magnetic principles
Performance Indicator 2 (CO2 - PO1, PO2, PO3, PO12)	Accurately analyzes thermoelectric effects, construction, and material suitability	Sound explanation with partial linkage to applications	Basic description of thermoelectric concepts with some gaps	Weak or incorrect correlation of material to application	Fails to explain or misrepresents thermoelectric principles
Performance Indicator 3 (CO3 - PO1, PO2, PO5, PO12)	Effectively evaluates classical and quantum transport models with accurate calculations	Good use of models with minor computational or conceptual errors	Basic understanding of models with limited calculation ability	Inconsistent explanation or poor calculation accuracy	No understanding of electrical transport models or calculations
Performance Indicator 4 (CO4 - PO1, PO2, PO4,	Clearly explains superconducting principles, types, and their techno-	Good grasp of concepts with minor classification or applica-	Some understanding of superconductors with few correct	Limited understanding of types or characteristics	Fails to explain superconductivity or its uses

PO12)	logical uses	tion errors	distinctions		
Performance Indicator 5 (CO5 - PO1, PO2, PO3, PO12)	Thoroughly describes rare earth, ceramic, and smart materials with strong application insights	Explains material characteristics with reasonable applications	Basic understanding of materials with unclear application contexts	Weak explanation of properties or selection justification	Fails to describe or apply materials correctly

Rubrics for CIE – Continuous assessment:

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator 1 (CO1 - PO1, PO2, PO3, PO12)	Explains dielectric and magnetic properties and their role in real components like transformers and capacitors with clarity	Good explanation with minor application errors	Basic understanding of properties but unclear application	Limited or incorrect linkage of concepts to components	Fails to explain or apply dielectric and magnetic principles
Performance Indicator 2 (CO2 - PO1, PO2, PO3, PO12)	Accurately analyzes thermoelectric effects, construction, and material suitability	Sound explanation with partial linkage to applications	Basic description of thermoelectric concepts with some gaps	Weak or incorrect correlation of material to application	Fails to explain or misrepresents thermoelectric principles
Performance Indicator 3 (CO3 - PO1, PO2, PO5, PO12)	Effectively evaluates classical and quantum transport models with accurate calculations	Good use of models with minor computational or conceptual errors	Basic understanding of models with limited calculation ability	Inconsistent explanation or poor calculation accuracy	No understanding of electrical transport models or calculations
Performance Indicator 4 (CO4 - PO1, PO2, PO4, PO12)	Clearly explains superconducting principles, types, and their technological uses	Good grasp of concepts with minor classification or application errors	Some understanding of superconductors with few correct distinctions	Limited understanding of types or characteristics	Fails to explain superconductivity or its uses
Performance Indicator 5 (CO5 - PO1, PO2, PO3, PO12)	Thoroughly describes rare earth, ceramic, and smart materials with strong application insights	Explains material characteristics with reasonable applications	Basic understanding of materials with unclear application contexts	Weak explanation of properties or selection justification	Fails to describe or apply materials correctly

Rubrics for SEE / CIE Test:

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator 1 (CO1 - PO1, PO2, PO3, PO12)	Explains dielectric and magnetic properties and their role in real components like transformers and capacitors with clarity	Good explanation with minor application errors	Basic understanding of properties but unclear application	Limited or incorrect linkage of concepts to components	Fails to explain or apply dielectric and magnetic principles
Performance Indicator 2	Accurately analyzes thermoelec-	Sound explanation with	Basic description of thermoe-	Weak or incorrect correlation	Fails to explain or misrepresents

(CO2 - PO1, PO2, PO3, PO12)	tric effects, construction, and material suitability	partial linkage to applications	lectric concepts with some gaps	of material to application	thermoelectric principles
Performance Indicator 3 (CO3 - PO1, PO2, PO5, PO12)	Effectively evaluates classical and quantum transport models with accurate calculations	Good use of models with minor computational or conceptual errors	Basic understanding of models with limited calculation ability	Inconsistent explanation or poor calculation accuracy	No understanding of electrical transport models or calculations
Performance Indicator 4 (CO4 - PO1, PO2, PO4, PO12)	Clearly explains superconducting principles, types, and their technological uses	Good grasp of concepts with minor classification or application errors	Some understanding of superconductors with few correct distinctions	Limited understanding of types or characteristics	Fails to explain superconductivity or its uses
Performance Indicator 5 (CO5 - PO1, PO2, PO3, PO12)	Thoroughly describes rare earth, ceramic, and smart materials with strong application insights	Explains material characteristics with reasonable applications	Basic understanding of materials with unclear application contexts	Weak explanation of properties or selection justification	Fails to describe or apply materials correctly

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 & PO8)	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) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth.	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)

	(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