SIDDAGANGA INSTITUTE OF TECHNOLOGY, TUMAKURU - 03

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

ELECTRICAL ENGINEERING MATERIALS

(For EE Branch)

Course Type: Integrated

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

Course objectives:
This course will enable students to:

1	Understand the properties of dielectrics and magnetic materials.
2	Know the thermal properties of materials and their applications relevant to engineering.
3	Analyze the electrical properties of metals using classical and quantum models.
4	Study the concept of band formation in solids and Hall Effect
5	Explore superconductivity principles, phenomena, and their applications

UNIT I

Dielectric and Magnetic Materials:

Dielectrics: Introduction – Dielectrics, Solid, Liquid and Gaseous dielectrics, Polar and non-polar dielectrics, Electrical Polarization Mechanisms, Internal fields in solids (qualitative), Clausius-Mossotti relation, (Derivation) and its implications, Frequency dependence of Dielectric constant, Dielectric loss. Applications of dielectrics in Capacitors, Transformers, Numerical Problems.

Magnetic material: Classification of magnetic materials, Hysteresis curve and explanation using Domain theory, Hard and soft magnetic materials, Applications - Transformer Cores, magnetic data storage, Numerical Problems.

Pre-requisites: Basics of dielectrics and magnetic materials.

Self-learning: Electric dipolemoment, Bohr magneton.

8 Hours

UNIT II

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

Prerequisites: Basics of thermal conductivity

Self-learning:Thermo emf, thermo current

8 Hours

UNIT III

Electrical Properties of Metals

Assumptions of classical free electron theory, drift velocity, relaxation time, collision time, Expression for electrical conductivity, mobility of electrons, Mechanisms of electron scattering in solids, Matheissen's rule, Failures of classical free electron theory. Assumptions of Quantum Free Electron Theory, Density of States (qualitative), Fermi Energy (qualitative), Expression of Fermi energy in terms of resistivity of a wire, significance of Fermi energy, Fermi Dirac statistics, Variation of Fermi Factor with Temperature, Fermi velocity, Fermi mean free path, Fermi temperature, Success of quantum free electron theory, concept of perfect conductor, Failures of QFE theory, Numerical Problems.

Prerequisites: Basics of electrical properties
Self-learning: Electrical conductivity

8 Hours

UNIT IV

Semiconductors

Classification of solids based on the formation of bands due to splitting of energy levels at equilibrium inter-nuclear distance: metal (Na & Mg), insulator (diamond) and semiconductor (Si). 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), Expression for electrical conductivity of a semiconductor. Hall effect in semiconductor, Expression for Hall coefficient and Hall voltage, Applications of Hall effect, Numerical Problems.

Prerequisites: Basics of semiconductor
Self-learning: Effective mass

8 Hours

UNIT V

Superconductivity

Introduction to superconductors, Temperature dependence of resistivity, Critical temperature,

Critical magnetic field, Meissner effect, Critical current, Temperature dependence of critical field, BCS theory (qualitative), Types of super conductors, High temperature superconductivity, Limitations of BCS theory, Quantum tunneling (qualitative), Josephson Junction, Flux quantization, DC SQUIDs (qualitative), Applications - superconducting magnet, Maglev Vehicle, Numerical Problems. **Prerequisites:** Basics of electrical conductivity **Self-learning:** Tunnelling Effect
8 Hours

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

REFERENCE BOOKS		
1	S Mani Naidu	Engineering Physics , Pearson, Fourteenth Impression, 2024.
2	S. O. Pillai	Solid State Physics, 8th Ed- New Age International Publishers-2018
3	Mishra, P. K.	Superconductivity – Basics and Applications. Ane Books, 2009.
4	Gaur and Gupta	Engineering Physics, Dhanpat Rai Publications, 2017
5	R. K. Shukla,	Electrical Engineering Materials, 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 03: Measurement Systems Characteristics – https://www.youtube.com/watch?v=Hlvbr5DCEfM
8. Lecture 05: Moving Iron Instruments – https://www.youtube.com/watch?v=TgGMqVPsaK0

9. Lecture 23: Error Calculation & Uncertainty – https://www.youtube.com/watch?v=ZpYGQQAix0E
10. Electrical Measurement course Prof Avishek Chatterjee IIT Kharagpur : https://www.youtube.com/playlist?list=PLbRMhDVUMngcoKrA4sH-zvbNVSE6IpEio

LIST OF EXPERIMENTS

1. Determination of Magnetic Flux Density at any point along the axis of a circular coil.
2. Determination of the dielectric constant of the material of a capacitor by Charging and Discharging Method.
3. Study the characteristics of a Photo-Diode and determine the power responsivity
4. Study the frequency response of Series & Parallel LCR circuits.
5. Determination of the Fermi Energy of Copper wire.
6. Determination of resistivity of a semiconductor by Four Probe Method.
7. B-H Curve
8. Thermo-emf or Peltier Module
9. Identification of Electronic and Electrical Components and Determination of Value – Black Box
10. Energy Gap of a Semiconductor
11. I-V Characteristics of a Bipolar Junction Transistor.
12. I-V Characteristics of a Zener diode.
13. Determination of the wavelength of semiconductor laser using Diffraction Grating.
14. Construction and Analyzing Electronic circuits (Expeyes Simulator / circuit lab)
15. Light Emitting Diode
16. Data analysis using spread sheet

Note: Any ten experiments to be conducted from the above list by covering one a) Open Ended experiment with spread sheet 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 theory of dielectrics to find dielectric constant, polarizability of the materials and be able to elucidate the applications of hard and soft magnetic materials for engineering applications.
CO2	Analyze thermoelectric phenomena, device construction, and identify suitable materials and applications for energy conversion.
CO3	Evaluate electrical transport mechanisms in metals using classical and quantum models and perform relevant calculations.

CO4	Apply the concepts of semiconductors to find mobility of charge carriers, conductivity of the materials, type and concentration of charge carriers in the semiconductor, Hall coefficient and Hall voltage.
CO5	Apply the theory of superconductivity to find critical temperature and critical field for superconducting state of the materials.

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	-	-	-	-	-	-	-	-	-	-	-