Semester

Thermoelectric Materials			
Course Code	21PHY752	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	2:2:0:1	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03 Hours

Course objectives:

To understand the fundamentals of thermoelectric materials, various types of thermoelectric devices and their applications

Teaching-Learning Process (General Instructions)

These are sample Strategies, which teacher can use to accelerate the attainment of the various course outcomes.

1. Apart from conventional lecture methods various types of innovative teaching techniques through videos, animation films may be adopted so that the delivered lesson can progress the students in theoretical, applied and practical skills in physics.
2. State the necessity of physics in engineering studies and offer real life examples.
3. Seminars and Quizzes may be arranged for students in respective subjects to develop skills.
4. Encourage the students for group learning to improve their creativity and analytical skills.
5. While teaching show how every concept can be applied to the real world. This helps the students to expand understanding level.
6. Support and guide the students for self-study.
7. Ask some higher order thinking questions in the class, which promotes critical thinking.
8. 8. Inspire the students towards the studies by giving new ideas and examples.

Module-1

Thermoelectric Properties and measurements: 08 Hours.

Introduction, Electrical Conductivity, Seebeck Coefficient, Thermal Conductivity, Electronic Thermal Conductivity, Lattice Thermal Conductivity, Figure of Merit. Two Probe and Four Probe Method of Measuring Electrical Resistivity, Integral and Differential Method of Measuring Seebeck Coefficient, Laser Flash Method of Measuring Thermal Conductivity, Hall Measurement.

Pedagogy	Chalk and talk, Power point presentation, Videos **Self-study Component:** Introduction to thermoelectric materials. Electrical and thermal Conductivity.

Module-2

Types of Thermoelectric Material: 08 Hours.

Low Temperature – BiSb, CsBi4Te6, FeSb2, YbAgCu4, Mid Temperature – Chalcogenides, Skutterudites, Tetrahedrites, BiCuSeO, High Temperature – Lanthanum Telluride, SiGe, WS2.

Pedagogy	Chalk and talk, Power point presentation, Videos **Self study Component: Brief information on low, mid and high temperature materials.**

Module-3

Concept of Charge Carriers, Phonons and Scattering Mechanism: 08 Hours.

Origin of Charge Carriers, Electron Dispersion Relation, Electron Distribution Function, Phonon, Dispersion Relation, Electron/Hole-Phonon Scattering, Charge Impurity Scattering, Grain Boundary Scattering, Point Defect and Alloy Scattering, Phonon Electron/Hole Scattering, Grain Boundary Scattering and Microstructure.

Pedagogy	Chalk and talk, Power point presentation, Videos **Self study Component: Wave**- Charge carriers and Origin of Charge carriers.

Module-4	
Concepts of Decoupling the Thermoelectric Parameters: 08 Hours. Concept of Decoupling of interrelated parameters (*S, σ, κ_e,* and *κ_l)*, Doping, Filling Voids, Microstructure Control, Concept of Phonon-Glass Electron, Crystal (PGEC) and Phonon-Liquid Electron Crystal (PLEC), Decoupling of power factor and thermal conductivity.	
Pedagogy	Chalk and talk, Power point presentation, Videos **Self study Component: Concept of decoupling.**
Module-5	
Thermoelectric Devices and Applications: 08 Hours. Fabrication, Measurement of Device, Applications – Exhaust of Automobiles, Refrigerators, Industries, Space Programs (RTG), Electricity Generation, Air-conditioning, Biomedical Devices, Particular Heating and Cooling. Biomass Cooking Stoves, Camping stoves and grills. Microprocessor cooling	
Pedagogy	Chalk and talk, Power point presentation, Videos **Practical Topics:** **Self study Component:** Various thermoelectric devices.
Course Outcomes After the completion of the course student should be able to : 1. Elucidate the thermoelectric properties of materials and their measurements. 2. Describe the various types of thermo-electric materials 3. Apprehend on the various scattering mechanisms of charge carriers and phonons. 4. Analyse various decoupling concepts of the thermoelectric parameters. 5. Describe the applications of thermoelectric devices.	

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 35% (18 Marks out of 50)in the semester-end examination(SEE).

Continuous Internal Evaluation:

Three Unit Tests each of **20 Marks (duration 01 hour**)

1. First test at the end of 5th week of the semester
2. Second test at the end of the 10th week of the semester
3. Third test at the end of the 15th week of the semester

Two assignments each of **10 Marks**

4. First assignment at the end of 4th week of the semester
5. Second assignment at the end of 9th week of the semester

Group discussion/Seminar/quiz any one of three suitably planned to attain the COs and POs for **20 Marks** (**duration 01 hours**)

6. At the end of the 13th week of the semester

The sum of three tests, two assignments, and quiz/seminar/group discussion will be out of 100 marks and will be **scaled down to 50 marks**

(To have less stressed CIE, the portion of the syllabus should not be common /repeated for any of the methods of the CIE. Each method of CIE should have a different syllabus portion of the course).

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester End Examination:

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the subject (**duration 03 hours)**

1. The question paper will have ten questions. Each question is set for 20 marks.
2. There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 3 sub-questions), **should have a mix of topics** under that module.

The students have to answer 5 full questions, selecting one full question from each module. Marks scored out of 100 shall be reduced proportionally to 50 marks

Suggested Learning Resources:

Text books:

Reference books:

1. Thermoelectric Materials and Devices. Netherlands: Elsevier Science, Chen, L., Liu, R., Shi, X. (2020).
2. Thermoelectricity and Advanced Thermoelectric Materials. United Kingdom: Elsevier Science, Editors Ranber Singh, Ranjan Kuma (2021).
3. The Physics of Thermoelectric Energy Conversion.United Kingdom: Morgan & Claypool Publishers. Goldsmid, J. (2017).
4. CRC Handbook of Thermoelectric. United Kingdom: CRC Press.(2018).
5. Thermoelectric: Design and Materials. Germany: Wiley Lee,H. (2016).
6. **Fundamentals Of Thermoelectricity by Behnia, Oxford UP**

Web links and Video Lectures (e-Resources):

1. https://youtu.be/_q7P9UCae1o
2. https://youtu.be/nx8q2ZrgGYE
3. https://youtu.be/fmsQJYPpZ2o
4. https://youtu.be/733oKZyhxyE

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

http://nptel.ac.in

https://swayam.gov.in