Course Code	Course Title	L	P	U
PHY211T	**Thermodynamics**	**4**	**0**	**4**

Course objectives: **Thermodynamics** course is designed for undergraduate physics students and deals with the fundamental aspects of thermodynamics.

- The main emphasis is placed on precise and logical presentation of the topics so that the student can understand the basic concepts and principles of thermodynamics and their usefulness.
- The content comprises the fundamental laws of thermodynamics, application of the laws for physical systems and formulation of complex thermodynamic functions in terms of measurable quantities.
- The course presents a comprehensive and rigorous treatment of classical thermodynamics while retaining the physics and physical arguments.
- This course will be instrumental in development of analytic capability required to evaluate various thermodynamic cycles used for energy production - work and heat, within the natural limits of conversion.
- At the end of the course the students will be able to gain the knowledge of the essential tools necessary to study thermodynamic systems.

Course Outcomes: On completion of course, the learners will be able to

- ✓ Identify the unique vocabulary associated with thermodynamics and Explain the basic concepts of thermodynamics like system, properties, equilibrium, pressure, specific volume, temperature, zeroth law of thermodynamics, temperature measurement and temperature scales.
- ✓ Explain the concept of thermodynamic workand apply the first law of thermodynamics for closed and open systems undergoing different thermodynamic processes.
- ✓ Prove the equivalence of second law of thermodynamics and state the propositions regarding efficiency of Carnot cycle.
- ✓ Evaluate the feasibility of a thermodynamic cycle using the second law of thermodynamics and quantify the second law of thermodynamics for a cycle by establishing the inequality of Clausius.
- ✓ Apply the inequality of Clausius and establish the property entropy of a system.
- ✓ Understand the Joule-Thomson Effect, Liquefaction of Gases, and third law of thermodynamics.

The learners on completion of **PHY211T***course will acquire* a thorough understanding of the theory and methods of *thermodynamics* that will be helpful in preparing them for advanced studies.

Syllabus:

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Unit I: Thermodynamic System and Concept of Thermodynamic Equilibrium: Thermodynamic System (thermodynamic variables and equation of state, limitations, classes of system), Zeroth Law of Thermodynamics, Concepts of Heat and Thermodynamic Equilibrium

Unit II: First law of Thermodynamics and Applications of First Law: Work: A path dependent function; Internal Energy; First law of Thermodynamics; Internal Energy as a State Function; Specific Heats of a Gas, Work: A path dependent function; Internal Energy; First law of Thermodynamics; Internal Energy as a State Function; Specific Heats of a Gas, Specific Heats of a Gas (V and T independent), Isochoric process, Isobaric process, Adiabatic process, Cyclic process, Non-isolated system, Isothermal process, The Indicator Diagram, Work done During an Isothermal Process, Work done During an Adiabatic Process, Slopes of Adiabatics and Isothermals, Relation between Adiabatic and Isothermal Elasticities

Reversible, Irreversible process and Carnot cycle: Heat Engine and Efficiency, Reversible and Irreversible Process, Conditions of Reversibility, Carnot's Engine and Carnot's Cycle, Reversible and Irreversible Engines, Reversibility of Carnot's Cycle, Two Carnot's Engines operating in series

Unit III: The Second Law of Thermodynamics and Entropy: Kelvin-Planck Statement and Clausius Statement of the Second Law, Carnot's Theorem, Thermodynamic (orAbsolute or Work) Scale of Temperature, Identity of Perfect Gas Scale and Absolute Scale, Physical Concept of Entropy and its Unit, Change of Entropy in Reversible and Irreversible Processes, Entropy and Unavailable Energy, Entropy and Disorder, Formulation of the Second Law in Terms of Entropy, Entropy and the Second Law, Temperature-Entropy (T-S) Diagram, Calculation of Entropy

Maxwell's Thermodynamic Relations and Simple Applications: Thermodynamic Variables, Extensive and Intensive Variables, Maxwell's Thermodynamic Relations, Applications of Maxwell's Thermodynamic Relations (Specific Heat Equation, Joule-Thomson Cooling, Joule-Thomson Coefficient, Temperature Change in Adiabatic Process, Clausius-Clapeyron's Equation)

Unit IV: Thermodynamic potentials and their applications: Thermodynamic Potentials, Significance of Thermodynamic Potentials, Relation of Thermodynamical Potentials with Their Variables, Relations Between cp, cv and μ, The T-dS Equations, Clapeyron's Latent Heat Equation (Using Thermodynamical Relations), Clapeyron's Latent Heat Equation (Using Carnot's Cycle), Equilibrium Between Liquid and its Vapour, First Order Phase Transitions, Second Order Phase Transitions :Ehrenfest's Equations, Triple point, Gibbs' Phase Rule

Unit V: The Third Law of Thermodynamics and Production of Low Temperatures: Different Methods of Cooling, Joule-Thomson Effect, Liquefaction of Gases, Liquid Helium; Cooling by Adiabatic Demagnetization; The Third Law of Thermodynamics

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Problem solving skill development course.

Text books(s):

T1: *Heat Thermodynamics and Statistical Physics: Subrahmaniyam N. & et Al., S. Chand & Company Ltd., Revised Edition 2007*

T2: *Thermodynamics & Statistical Physics: S.S. Singhal, J.P. Agarwal, Satya Prakash, Pragati Prakashan, 2017*

Reference book(s):

R1: *Heat and Thermodynamics - Special Indian Edition: Mark Zemansky& Richard Dittman, Mc Graw Hill Education, 8th Edition*

R2: *Thermal Physics: with Kinetic Theory, Thermodynamics and Statistical Mechanics: S.C. Garg, R.M. Bansal & C.K. Ghosh, Mc Graw Hill Education, 2nd Edition, 2017*

R3: *IGNOU Study Materials: PHE-06 : Thermodynamics and Statistical Mechanics*

Lecture wise plan:

Lecture Nos.	Learning objective	Topics to be covered	Chap./Sec. (Text Book)
1 –5	Zeroth law and concept of thermodynamic equilibrium	Thermodynamic System (thermodynamic variables and equation of state, limitations, classes of system),Zeroth Law of Thermodynamics, Concepts of Heat and Thermodynamic Equilibrium	T1: 4.1 – 4.4
6– 11	First law of Thermodynamics	Work: A path dependent function; Internal Energy; First law of Thermodynamics; Internal Energy as a State Function; Specific Heats of a Gas	T1: 4.5 – 4.9
12 – 17	Applications of the First law of Thermodynamics	Specific Heats of a Gas (V and T independent), Isochoric process, Isobaric process, Adiabatic process, Cyclic process, Non-isolated system, Isothermal process, The Indicator Diagram, Work done During an Isothermal Process, Work done During an Adiabatic Process, Slopes of Adiabatics and Isothermals, Relation between Adiabatic and Isothermal Elasticities	T1: 4.10 – 4.15

18–24	Reversible, Irreversible process and Carnot cycle	Heat Engine and Efficiency, Reversible and Irreversible Process, Conditions of Reversibility, Carnot's Engine and Carnot's Cycle, Reversible and Irreversible Engines, Reversibility of Carnot's Cycle, Two Carnot's Engines operating in series	T1: 4.20 T2: 2.1- 2.7
25– 30	The Second Law of Thermodynamics	Kelvin-Planck Statement and Clausius Statement of the Second Law, Carnot's Theorem, Thermodynamic (or Absolute or Work) Scale of Temperature, Identity of Perfect Gas Scale and Absolute Scale	T2: 2.8- 2.11
31– 36	Entropy	Physical Concept of Entropy and its Unit, Change of Entropy in Reversible and Irreversible Processes, Entropy and Unavailable Energy, Entropy and Disorder, Formulation of the Second Law in Terms of Entropy, Entropy and the Second Law, Temperature-Entropy (T-S) Diagram, Calculation of Entropy	T2: 2.13 – 2.18, 2.20, 2.21
37–42	Maxwell's thermodynamic relations and simple applications	Thermodynamic Variables, Extensive and Intensive Variables, Maxwell's Thermodynamic Relations, Applications of Maxwell's Thermodynamic Relations (Specific Heat Equation, Joule-Thomson Cooling, Joule-Thomson Coefficient, Temperature Change in Adiabatic Process, Clausius-Clapeyron's Equation)	T1: 6.1 – 6.4
43– 49	Thermodynamic potentials and their applications	Thermodynamic Potentials, Significance of Thermodynamic Potentials, Relation of Thermodynamical Potentials with Their Variables, Relations Between *cp*, *cv* and μ, TheT-dS Equations, Clapeyron's Latent Heat Equation (Using Thermodynamical Relations), Clapeyron's Latent Heat Equation (Using Carnot's Cycle)	T1: 6.5 – 6.11
50–54	Phase transitions and Clausius-Clapeyron equation.	Equilibrium Between Liquid and its Vapour, First Order Phase Transitions, Second Order Phase Transitions :Ehrenfest's Equations, Triple point, Gibbs' Phase Rule	T1: 6.17 – 6.19, 16.23, 16.24

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55–60	Production of Low Temperatures and the Third Law	Different Methods of Cooling, Joule-Thomson Effect, Liquefaction of Gases, Liquid Helium; Cooling by Adiabatic Demagnetization; The Third Law of Thermodynamics	T1: 7.1, 7.5, 7.6, 7.11 – 7.16, 5.15 – 5.18

Evaluation Scheme:

Component	Duration	Weightage(%)	Remarks
Internal I		25	Assignments/Quiz/Viva
Midterm	2 hours	20	
Internal II		25	Assignments/Quiz/Viva
Comprehensive	3 hours	30	

1. Attendance Policy: A Student must normally maintain a minimum of **75% attendance** in the course without which he/she shall be disqualified from appearing in the respective examination.

2. Chamber Consultation Hour: Course Instructor will announce in the class.(During the Chamber Consultation Hours, the students can consult in Faculty's chamber without prior appointment.)

3. Make-up Policy: A student, who misses any component of evaluation for genuine reasons, must immediately approach the instructor with a request for **make-up examination** stating reasons. **The decision of the instructor in all matters of make-up shall be final.**

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