# ADVANCED THERMODYNAMICS

**I Semester**

**Course Code:** 19ME2202

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**Prerequisites:** Engineering Thermodynamics

Course Outcomes: At the end of the course the student shall be able to

CO1: Apply the concept of entropy and irreversibility to solve practical problems.
CO2: Explain P-V, T-S, P-T and h-s diagrams of pure substance and its significance.
CO3: Distinguish the equations of state for ideal and real gases and gas mixtures.
CO4: Develop TdS, Maxwell's equations and power cycles.
CO5: Explain reactive system and its significance in combustion process.

**UNIT-I: (10-Lectures)**

Entropy: Clausius theorem - the property of entropy – the inequality of Clausius – entropy change in an irreversible process – entropy principle – applications of entropy principle to the processes of transfer of heat through a finite temperature difference, and mixing of two fluids maximum work obtainable from a finite body and a thermal energy reservoir – entropy transfer with heat flow - entropy generation in a closed system – entropy generation in an open system.

Learning Outcomes: At the end of this unit, the student will be able to

1. Illustrate the concept of entropy, principle of entropy and irreversibility (L2)
2. Describe the reversibility, irreversibility and impossibility of a thermodynamic cycle/process (L3)
3. Derive the maximum work obtained by a heat engine and to determine the entropy generation (L5)

**UNIT-II: (10-Lectures)**

Available energy: Available energy referred to a cycle - available energy from a finite energy source – maximum work in a reversible process – dead state – availability in a steady flow process – availability in a non-flow process – availability in chemical reactions. P-V-T Relationships for pure substances: P-v diagram for a pure substance, triple point line, critical point, saturated liquid and vapor lines, P-T diagram for a pure substance - T-s diagram for a pure substance – h-s diagram (Mollier diagram) for a pure substance – dryness fraction – problems using steam tables.

Learning Outcomes: At the end of this unit, the student will be able to

1. Illustrate the concept of available & unavailable energy refer to a cycle, process and determine the maximum and useful work (L2)
2. Determine the irreversibility of a process by applying Gouy-Stodola theorem (L5)
3. Demonstrate the phase change process of a pure substance on PV/PT/PVT surfaces and to extract its properties from Mollier diagram/steam tables (L1 & L2)

**UNIT-III: (10-Lectures)**

Properties of Gases: Equations of state – Vander Waal's equation – law of corresponding states – Beattie-Bridgeman equation, Redlich-Kwong equation. Gas Mixtures: Dalton's law of partial pressures – enthalpy and entropy of gas mixtures.

Learning Outcomes: At the end of this unit, the student will be able to

1. Develop the equation of state, distinguish real gas behavior from ideal gas with making use of various real gas equations (L3)
2. Determine the energy interactions and entropy change associated with various thermodynamic processes undergone by an ideal gas. (L5)
3. Calculate the properties of given gas and gas mixtures (L5)

**UNIT-IV: (10-Lectures)**

Thermodynamic Relations: Maxwell's equations –TdS equations – difference in heat capacities – ratio of heat capacities – Joule-Kelvin effect – Clausius-Clapeyron equation. Power Cycles: Brayton cycle – comparison between Brayton cycle and Rankine cycle – effect of regeneration on Brayton cycle efficiency – Brayton-Rankine combined cycle.

Learning Outcomes: At the end of this unit, the student will be able to

1. Develop Maxwell's, TDS and Clapeyron equations (L3)
2. Develop general relations for $C_v$, $C_p$, du, dh, and ds that are valid for all pure substances and discuss the Joule-Thomson coefficient (L5)
3. Demonstrate the working of Brayton and Rankine cycle and Explain various performance improving methods of it (L2)

**UNIT-V: (10-Lectures)**

Reactive Systems: Degree of reaction – reaction equilibrium – law of mass action – heat of reaction – temperature dependence of the heat of reaction – temperature dependence of the equilibrium constant – change in Gibbs function – Fugacity and activity. Chemical Reactions: Combustion, Theoretical and actual combustion processes – Enthalpy of formation – Enthalpy of Combustion – First Law analysis of Reacting Systems – Adiabatic flame temperature – Entropy change of Reacting mixtures – Second Law analysis of Reacting systems.

Learning Outcomes:

At the end of this unit, the student will be able to
1. Define degree of reaction, understand its limiting values (L1)
2. Define and evaluate the chemical equilibrium constant and to establish its relation with Gibbs function change (L1 & L5)
3. Determine air-fuel ratio, enthalpy of reaction, enthalpy of combustion, heating values of fuels and adiabatic flame temperature for reacting mixtures (L3)

**TEXT BOOKS:**

1. P.K. Nag, *Engineering Thermodynamics*, Sixth Edition, Tata McGraw-Hill Education Private Limited, 2017.

2. S.S. Thipse, *Advanced Thermodynamics*, Narosa Publishing House, New Delhi, 2013.

**REFERENCE BOOKS:**

1. Y.A. Cengel and M.A. Boles, *Thermodynamics – An Engineering Approach*, Eighth Edition in SI Units, Tata McGraw Hill Publishing Company Limited, New Delhi, 2017.
2. C. Borganakke and R.E. Sonntag, *Fundamentals of Thermodynamics*, Ninth Edition, Wiley India, Delhi, 2017.