ADVANCED THERMODYNAMICS

Course Code: 13ME2302 **L P C**
4 0 3

Pre requisites: Basic thermodynamics, Statistics

Course Educational Objectives:
To make the student understand
1. the principle of entropy, and entropy generation in closed and open systems
2. the concepts of availability and irreversibility
3. properties of gases and gas mixtures, and thermodynamic relations
4. thermodynamics of reactive systems and chemical equilibrium
5. certain advanced power cycles
6. concepts of statistical thermodynamics

Course Outcomes:
The student will be able to
1. apply the principles of entropy and irreversibility to solve practical problems
2. explain the equations of state for ideal and real gases and gas mixtures
3. use thermodynamic relations to predict latent heats and other properties of substances
4. explain combined power cycles
5. explain thermodynamic distribution function and partition function in classical thermodynamics

UNIT-I
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.

UNIT-II

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.

UNIT-III

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.

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.

UNIT-IV

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.

Statistical Thermodynamics-I: Thermodynamic equilibrium distribution – thermodynamic distribution function – thermodynamic ensemble, micro canonical ensemble, canonical ensemble, grand canonical ensemble.

UNIT-V

Statistical Thermodynamics-II: Maxwell-Boltzmann statistics and distribution – Fermi-Dirac statistics and distribution – Bose-Einstein statistics and distribution – phase space – Liouville equation – equilibrium constant by statistical thermodynamic approach.

Partition function – equipartition of energy – partition function for canonical ensemble – partition function for an ideal monoatomic gas – decomposition of partition function – translational partition function – electronic, rotational and vibrational partition functions.

TEXT BOOKS:

1. P.K. Nag, "*Engineering Thermodynamics"*, 4th Edition, Tata McGraw-Hill Education Private Limited, 2010.

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

REFERENCES:

1. Y.A. Cengel and M.A. Boles, "*Thermodynamics – An Engineering Approach"*, 5th Edition in SI Units, Tata McGraw Hill Publishing Company Limited, New Delhi, 2006.

2. C. Borganakke and R.E. Sonntag, "*Fundamentals of Thermodynamics"*, 7th Edition,
Wiley India, Delhi, 2012.

3. Van P. Carey, "Statistical thermodynamics and micro scale thermo physics", Cambridge University Press, 1999