



Chapter 1

Chapter 1 : Basic Concepts 1-1 to 1-30

Syllabus : Thermodynamic system and control volume, Microscopic and macroscopic point of view, thermodynamic properties, state of a substance, process and cycle, Thermodynamic equilibrium, Concept of Continuum, Quasi-static process, The Zeroth Law of Thermodynamics, Temperature scales.

1.1	Definition of Thermodynamics	1-1
1.2	Thermodynamics System	1-1
1.2.1	Classification of Thermodynamic Systems	1-2
1.2.2	Homogeneous and Heterogeneous Systems.....	1-3
1.3	Microscopic and Macroscopic Points of View	1-3
1.4	Pure Substance	1-4
1.5	Dimensions and Units.....	1-4
1.6	Energy	1-5
1.6.1	Internal Energy	1-5
1.6.2	External Energy	1-5
1.6.3	Total Energy, E	1-6
1.7	State and Property	1-6
1.7.1	Classification of Properties	1-6
1.8	Thermodynamic Processes and Cycles.....	1-8
1.9	Thermodynamic Equilibrium	1-8
1.10	Quasistatic Process.....	1-9
1.10.1	Types of Processes	1-10
1.10.2	Working Substance	1-10
1.11	Pressure and It's Measurements	1-10
1.11.1	Barometric Pressure.....	1-10
1.11.2	Pressure Measuring Devices	1-11
1.12	Temperature.....	1-12
1.13	Thermal Equilibrium (Equality of Temperature).....	1-13
1.14	Zeroth Law of Thermodynamics	1-13
1.15	Thermometers	1-13
1.16	Temperature Scale.....	1-15
1.16.1	Celsius Scale.....	1-15
1.16.2	Fahrenheit Scale	1-15
1.16.3	Kelvin Temperature Scale	1-15
1.16.4	International Practical Temperature Scale	1-16
1.17	Review of Some of Basic Equations and Concepts ...	1-20
1.17.1	Point Function	1-20
1.17.2	Path Function	1-20
1.17.3	Heat.....	1-20
1.17.4	Work.....	1-21
1.17.5	Workdone in Moving a Boundary of a Closed System in a Quasi-static Process (Displacement Work)	1-22
1.17.5.1	Limitations of $\int p \cdot dV$ Work.....	1-23
1.17.5.2	Work is a Path Function	1-23
1.17.5.3	Units of Work	1-24
1.17.5.4	Power	1-24
1.17.5.5	Sign Convention	1-24
1.17.5.6	Similarities between Heat and Work	1-24
1.17.5.7	Differences between Heat and Work	1-24
1.17.6	Enthalpy	1-24
1.17.7	Important formulae	1-25
1.17.8	Specific Heat of a Substance.....	1-25
1.17.9	Specific Heats for Ideal Gases	1-25
1.17.10	Ratio of Two Specific Heats C_p and C_v	1-25
1.18	University Questions with Answers	1-29



Chapter 2

Chapter 2 : First Law of Thermodynamics 2-1 to 2-60

Syllabus : First law for a closed system undergoing a cycle and change of state, energy, PMM1, first law of thermodynamics for steady flow process, steady flow energy equation applied to nozzle, diffuser, boiler, turbine, compressor, pump, heat exchanger and throttling process, filling and emptying process.

2.1	Law of Conservation of Energy	2-1
2.2	First Law of Thermodynamics (Joule's Experiment)....	2-1
2.3	Corollaries of First Law	2-2
2.3.1	Corollary 1 [Perpetual Motion Machine of the First Kind [PMM-1]]	2-2
2.4	Corollary 2 (First Law for a Process and Total Energy/Internal Energy Is a Property of System)	2-3
2.5	Corollary 3 (First Law of an Isolated System).....	2-4
2.6	Internal Energy	2-4
2.7	Joule's Law.....	2-4
2.8	Application of First Law of Thermodynamics as Applied to Closed System or Non Flow Processes ...	2-9
2.9	Constant Volume Process (Closed System or Non Flow Process)	2-9
2.10	Constant Pressure Process	2-11
2.11	Constant Temperature or Isothermal Process	2-13
2.12	Hyperbolic Process	2-14
2.13	Reversible Adiabatic Process	2-15
2.14	Polytropic Process.....	2-16
2.15	Application of First Law of Thermodynamics as Applied to Open Systems	2-27
2.15.1	Mass Balance for Unsteady Flow System	2-27
2.15.2	Mass Balance for Steady Flow System (Continuity Equation)	2-27

2.15.3	Flow Work or Flow Energy	2-28
2.15.4	Energy Balance for Steady Flow Open System	2-28
2.16	Mechanical Work in Steady Flow System	2-29
2.16.1	Meaning $\int -V dp$ Work	2-29
2.16.2	Limitations of $\int -V dp$ Work	2-30
2.16.3	Difference between $\int -V dp$ and $\int p dV$ Work	2-30
2.17	Calculations of $\int -V dp$ Work as Applied to Open System Processes for Ideal Gases	2-30
2.17.1	Constant Volume Process ($V = C$ i.e. $V_1 = V_2 = V = C$).....	2-30
2.17.2	Constant Pressure Process ($p = c$)	2-30
2.17.3	Isothermal or Constant Temperature Process	2-30
2.17.4	Hyperbolic Process, According to Law $p .V = C$	2-30
2.17.5	Reversible Adiabatic Process	2-30
2.17.6	Polytropic Process	2-31
2.18	Throttling Process	2-31
2.18.1	Free Expansion	2-32
2.19	Application of Steady Flow Energy Equation to Engineering Devices	2-34
2.20	Nozzles and Diffusers	2-34
2.21	Hydraulic Turbines and Pumps	2-35
2.22	Gas Turbines and Compressors	2-36
2.23	Heat Exchanger.....	2-36
2.23	Boiler	2-37
2.25	Combustion Chamber	2-37
2.26	General Notes	2-37
2.27	Unsteady Flow Processes	2-47
2.27.1	Charging a Tank	2-47
2.28.2	Discharge From the Tank	2-47
2.28	University Questions with Answers	2-58



Chapter 3

Chapter 3 : Second Law of Thermodynamics 3-1 to 3-38

Syllabus : Limitations of First Law of thermodynamics, Kelvin-Planck and Clausius statements and their equivalence, PMM2, causes of irreversibility, Carnot theorem, corollary of Carnot theorem, thermodynamic temperature scale.

3.1	Limitations of First Law of Thermodynamics	3-1
3.2	Definitions	3-3
3.2.1	Thermal Efficiency of a Heat Engine	3-3
3.2.2	Coefficient of Performance (C.O.P)	3-4
3.3	Second Law of Thermodynamics	3-4
3.4	Perpetual Motion Machines (P.M.M)	3-5
3.5	Equivalency of Clausius and Kelvin - Planck Statements	3-5
3.6	Work is a High Grade Energy and Heat is a Low Grade Energy	3-7
3.7	Reversible and Irreversible Processes	3-7
3.7.1	Reversible Process	3-7
3.7.2	Irreversible Process	3-7
3.7.3	Causes of Irreversibility	3-8
3.7.4	External Irreversibility.....	3-8
3.7.5	Internal Irreversibility.....	3-9
3.7.6	Chemical Irreversibility.....	3-10
3.8	Conditions for Reversibility	3-10
3.9	Carnot Cycle	3-10
3.9.1	Carnot Cycle Processes	3-10
3.9.2	Efficiency of Carnot Engine	3-11
3.9.3	Carnot Refrigerator and Carnot Heat Pump	3-12
3.10	Carnot's Theorem (Corollary of II nd Law)	3-13
3.11	Absolute Thermodynamic Temperature Scale	3-14
3.12	Comparison of I st Law and II nd Law of Thermodynamics	3-16

3.13	University Questions with Answers	3-37
------	---	------

Chapter 4

Chapter 4 : Entropy

4-1 to 4-34

Syllabus : Clausius theorem, property of entropy, inequality of Clausius, entropy change in an irreversible process, principle of increase of entropy, entropy change for non-flow and flow processes.

4.1	Introduction	4-1
4.2	Two Reversible Adiabatic Paths cannot Intersect each other	4-1
4.3	Any Reversible Process can be Replaced by two Reversible Adiabatics with one Reversible Isotherm between them	4-1
4.4	Clausius Inequality	4-2
4.5	Entropy - A Property of the System	4-6
4.6	Entropy Change of Heat and Work Reservoirs	4-7
4.7	Principle of Increase of Entropy	4-7
4.8	Entropy Change of Reversible Adiabatic and Reversible Isothermal Processes	4-8
4.9	Some Important Points Regarding Entropy	4-9
4.10	Temperature - Entropy (T - S) Diagram	4-9
4.10.1	Carnot Cycle on (T - S) Diagram	4-10
4.11	TdS Relations and Change of Entropy in Any Thermodynamic Process	4-11
4.11.1	Representation of Constant Volume and Constant Pressure Processes on (T - S) Diagram	4-11
4.12	Entropy Change for Pure Substances	4-12
4.13	Third Law of Thermodynamics (Nernst Law)	4-13
4.14	Entropy and Disorder	4-13
4.15	Exergy	4-14
4.16	University Questions with Answers	4-32



Chapter 5

Chapter 5 : Exergy
5-1 to 5-26

Syllabus : Exergy of a heat input in a cycle, exergy destruction in heat transfer process, exergy of finite heat capacity body, exergy of closed and steady flow system, irreversibility and Gouy-Stodola theorem and its applications, second law efficiency.

5.1	Concept of Availability of Systems	5-1
5.1.1	Availability of Various Systems	5-2
5.2	Availability of Work Reservoirs	5-2
5.3	Availability of Heat Reservoir and Heat Energy	5-2
5.3.1	Reversible Cycle with Infinite Heat Source (Heat Reservoir)	5-2
5.3.2	Reversible Cycle with Finite Heat Reservoir	5-3
5.4	Decrease in Available Energy (A.E.) when Heat is Transferred Through a Finite Temperature Difference	5-3
5.5	Availability of a Closed System (Non-flow Processes)	5-11
5.6	Availability of Steady Flow Open System.....	5-15
5.7	Irreversibility of the Systems.....	5-16
5.8	Irreversibility of Closed System.....	5-17
5.9	Irreversibility of a Steady Flow Open System.....	5-17
5.9.1	Gouy Stodola Theorem.....	5-17
5.9.2	Application of Gouy Stodola Theorem in Heat Transfer Through a Finite Temperature Difference	5-18
5.10	Effectiveness or Second Law Efficiency	5-18
5.11	Importance of Availability, Effectiveness and Irreversibility	5-19
5.12	Comparison between Availability (Exergy) and Energy	5-19
5.13	University Questions with Answers	5-25

Chapter 6

Chapter 6 : Vapour Power Cycles
6-1 to 6-42

Syllabus : Carnot vapour cycle, Rankine cycle, comparison of Carnot and Rankine cycle, calculation of cycle efficiencies, variables affecting efficiency of Rankine cycle, reheat cycle, regenerative cycle, reheat-regenerative cycle, feed water heaters.

6.1	Objectives of Vapour Power Cycles	6-1
6.2	Basic Components of a Steam Power Plant	6-1
6.3	The Carnot Vapour Cycle	6-2
6.3.1	Practical Reasons due to which a Carnot Cycle is not Considered as Ideal Cycle for Vapour Power Plants	6-4
6.4	Rankine Cycle	6-4
6.4.1	Proof for Rankine Efficiency is Lower than Carnot Efficiency	6-6
6.4.2	Advantages of Rankine Cycle over Carnot Cycle	6-7
6.4.3	Comparison between Carnot and Rankine Cycle	6-7
6.4	Effect of Thermodynamics Variables on Efficiency and Output of Rankine Cycle	6-7
6.5.1	Effect of Superheating of Steam	6-7
6.5.2	Effect of Increase in Boiler Pressures	6-8
6.5.3	Effect of Increase in Condenser Pressure	6-8
6.6	Deviations from Theoretical Vapour Cycles (Isentropic Efficiency of Turbine)	6-9
6.7	Methods of Improving Ranking Efficiency	6-17
6.8	Rankine cycle with Reheat.....	6-17
6.9	Ideal Regenerative Cycle.....	6-21
6.10	Practical Regenerative Cycle.....	6-22
6.10.1	Advantages of Regenerative Cycle.....	6-24
6.10.2	Disadvantages of Regenerative Cycle	6-24
6.10.3	Types of Feed Water Heaters.....	6-24
6.11	Disposal of Bled Steam Condensation (Method of Feed Water Heating)	6-25



6.11.1	Direct Contact Feed Water Heaters	6-25
6.11.2	Drain Pump Method.....	6-25
6.11.3	All Drains in Hot-Well Method.....	6-26
6.11.4	Cascade Method.....	6-26
6.12	University Questions With Answers	6-40

Chapter 7

Chapter 7 : Gas Power Cycles	7-1 to 7-41
-------------------------------------	--------------------

Syllabus : Recapitulation of Carnot, Otto and Diesel cycle, Dual cycle, Comparison of Otto, Diesel and Dual cycles, air standard efficiency, mean effective pressure, brake thermal efficiency, relative efficiency, Simple Brayton cycle.

7.1	Concept of Air Standard Cycles	7-1
7.2	Assumptions of Air Standard Cycle	7-1
7.3	Clearance Volume, Swept Volume and Compression Ratio	7-1
7.4	Air Standard or Ideal Efficiency and Other Efficiencies	7-2
7.5	Work Ratio	7-2
7.6	Air Standard Otto Cycle	7-3
7.6.1	Condition for Maximum Work between Fixed Temperature Limits	7-5
7.7	Air Standard Diesel Cycle	7-11
7.7.1	Mean Effective Pressure	7-12
7.8	Air Standard Dual Combustion or Limited Pressure Cycle	7-13
7.8.1	Mean Effective Pressure	7-14
7.9	Comparison of Otto, Diesel and Dual - Combustion Cycles	7-14
7.9.1	If the Heat Supplied and the Compression Ratio is Same	7-14
7.9.2	For Same Maximum Pressure and Temperature	7-15
7.9.3	For Same Constant Maximum Pressure and Heat Supplied	7-16

7.9.4	For Same Compression Ratio and Heat Rejection.....	7-16
7.10	Brayton Cycle for Gas Turbine Power Plants	7-25
7.10.1	Optimum Pressure Ratio for Maximum Net Work	7-27
7.10.2	Intermediate Temperature T_2 for Optimum Work	7-28
7.10.3	Effect of Irreversibilities in Turbine and Compressor..	7-28
7.11	University Questions with Answers	7-39

Chapter 8

Chapter 8 : Refrigeration Cycles	8-1 to 8-38
---	--------------------

Syllabus : Simple Vapour Compression Refrigeration (VCR) cycle on P-h and T-s diagrams, analysis of the simple cycle, factors affecting the performance of the cycle, actual cycle, Reversed Carnot cycle and its limitation, Bell-Coleman cycle.

8.1	Air Refrigeration System	8-1
8.1.1	Types of Air Refrigeration System	8-1
8.1.2	Advantages of Closed System over Open System	8-1
8.1.3	Disadvantages of Closed System over Open System	8-1
8.2	Reversed Carnot Cycle or Carnot Refrigerator	8-1
8.2.1	Limitations of Carnot Cycle with Air or Gas as Refrigerant.....	8-2
8.2.2	Carnot Refrigerator with Vapour as Refrigerant	8-3
8.3	Bell-Coleman or Reversed Brayton or Reversed Joule Air Refrigeration Cycle	8-6
8.3.1	Advantages of Bell Coleman Cycle.....	8-7
8.3.2	Disadvantages of Bell-Coleman Cycle.....	8-7
8.3.3	Closed Bell-Coleman Air Cycle.....	8-7
8.4	Limitations of Air Refrigeration Cycle	8-15
8.4.1	Comparison of Vapour Compression (VC) and Air Refrigeration Cycles	8-15
8.5	The Vapour Compression Refrigeration System	8-16
8.5.1	Advantages and Disadvantages of Vapour Compression System over Air Refrigeration System	8-17



8.5.2	System Equipment Nomenclature	8-17	9.3	Chemical Reactions (Combustion Equations)	9-2
8.6	Pressure - Enthalpy (p-h) Chart for Refrigerants.....	8-17	9.4	Mass Fraction	9-3
8.7	Thermodynamic Analysis of Vapour Compression Refrigeration Cycle	8-18	9.5	Mole Fraction	9-3
8.7.1	When the Vapour is Dry-saturated at the End of Compression	8-18	9.6	Combustion Equation	9-3
8.7.2	Vapour Compression Cycle when Vapour is Wet at the End of Compression	8-20	9.7	Stoichiometric or Theoretical Air, Excess Air, Air-fuel Ratio and Mixture Strength	9-4
8.7.3	Vapour Compression Cycle when the Vapour is Dry- saturated at Entry to Compressor (Ideal Cycle or Standard Cycle).....	8-20	9.8	Determination of Minimum Air Required per kg of Solid or Liquid Fuel for Complete Combustion	9-4
8.7.4	Assumptions in Theoretical Vapour Compression Cycle	8-21	9.9	Determination of Flue Gas Analysis by Mass and by Volume	9-5
8.8	Wet Compression Vs Dry Compression.....	8-21	9.10	Combustion of Gaseous Fuels	9-11
8.9	Effect of Operating Variables on Performance of Vapour Compression Refrigeration System	8-21	9.11	Application of First Law of Thermodynamics to Combustion Processes	9-14
8.9.1	Effect of Superheat in Suction Vapour	8-21	9.12	Internal Energy of Reaction and Enthalpy of Reaction	9-15
8.9.2	Effect of Liquid Subcooling	8-22	9.12.1	At Constant Volume.....	9-15
8.9.3	Effect of Change in Suction Pressure	8-23	9.12.2	Constant Pressure Combustion Process	9-15
8.9.4	Effect of Change of High Side Pressure or Discharge Pressure or Condenser Pressure.....	8-23	9.12.3	Relationship between Q_p and Q_v	9-15
8.10	Expansion Cylinder Vs Throttle Valve	8-24	9.12.4	Higher and Lower Calorific Value or Heating Value of Fuels	9-16
8.11	Actual Vapour Compression Refrigeration Cycle	8-25	9.13	Enthalpy of Formation $(\Delta h_f^{\circ} \text{ or } \bar{h}_f^{\circ})$	9-17

Chapter 9

Chapter 9 : Combustion 9-1 to 9-28

Syllabus : Combustion equations, stoichiometric air fuel ratio, enthalpy of formation, adiabatic flame temperature, determination of calorific values of fuels - calorimeter - Bomb and Junkers gas calorimeter.

9.1	Introduction	9-1
9.2	Physical Laws of Combustion	9-1

9.3	Chemical Reactions (Combustion Equations)	9-2
9.4	Mass Fraction	9-3
9.5	Mole Fraction	9-3
9.6	Combustion Equation	9-3
9.7	Stoichiometric or Theoretical Air, Excess Air, Air-fuel Ratio and Mixture Strength	9-4
9.8	Determination of Minimum Air Required per kg of Solid or Liquid Fuel for Complete Combustion	9-4
9.9	Determination of Flue Gas Analysis by Mass and by Volume	9-5
9.10	Combustion of Gaseous Fuels	9-11
9.11	Application of First Law of Thermodynamics to Combustion Processes	9-14
9.12	Internal Energy of Reaction and Enthalpy of Reaction	9-15
9.12.1	At Constant Volume.....	9-15
9.12.2	Constant Pressure Combustion Process	9-15
9.12.3	Relationship between Q_p and Q_v	9-15
9.12.4	Higher and Lower Calorific Value or Heating Value of Fuels	9-16
9.13	Enthalpy of Formation $(\Delta h_f^{\circ} \text{ or } \bar{h}_f^{\circ})$	9-17
9.13.1	Specific Enthalpy of a Compound at (p, T)	9-18
9.13.2	Enthalpy of Formation Table.....	9-18
9.13.3	Application of Enthalpy of Formation	9-18
9.14	Adiabatic Flame Temperature	9-19
9.14.1	Equation for Adiabatic Flame Temperature.....	9-19
9.15	Experimental Determination of Calorific Value of Fuels	9-20
9.15.1	Cooling Correction	9-21
9.16	Boy's Gas Calorimeter	9-22
9.16.1	Junker Gas Calorimeter	9-23
• Appendix A		
A-1 to A-9		

