

# Contents

<b>Chapter 1</b>	<b>Introductory Concepts and Definitions</b>	<b>1</b>
	1.1 Thermodynamic Systems	2
	1.2 Property, State, Process, and Equilibrium	4
	1.3 Units for Mass, Length, Time, and Force	7
	1.4 Specific Volume and Pressure	9
	1.5 Temperature	13
	1.6 Methodology for Solving Thermodynamics Problems	18
	1.7 Engineering Design	20
<b>Chapter 2</b>	<b>Energy and the First Law of Thermodynamics</b>	<b>25</b>
	2.1 Mechanical Concepts of Energy	25
	2.2 Energy Transfer by Work	29
	2.3 Energy of a System	40
	2.4 Energy Transfer by Heat	44
	2.5 Energy Balance for Closed Systems	48
	2.6 Energy Analysis of Cycles	57
<b>Chapter 3</b>	<b>Properties of a Pure, Simple Compressible Substance</b>	<b>66</b>
	3.1 State Principle	66
	3.2 $p$ - $v$ - $T$ Relation	67
	3.3 Thermodynamic Property Data	73
	3.4 $p$ - $v$ - $T$ Relation for Gases	86
	3.5 Ideal Gas Model	92
<b>Chapter 4</b>	<b>Control Volume Energy Analysis</b>	<b>114</b>
	4.1 Conservation of Mass for a Control Volume	114
	4.2 Conservation of Energy for a Control Volume	120
	4.3 Analysis of Control Volumes at Steady State	125
	4.4 Transient Analysis	143
<b>Chapter 5</b>	<b>The Second Law of Thermodynamics</b>	<b>161</b>
	5.1 Introduction	161
	5.2 Statements of the Second Law	164
	5.3 Irreversible and Reversible Processes	166
	5.4 Second Law Corollaries for Thermodynamic Cycles	173
	5.5 Kelvin Temperature Scale	178

- 5.6 Maximum Performance Measures for Power, Refrigeration, and Heat Pump Cycles Operating Between Two Reservoirs 181
- 5.7 Carnot Cycle 186

## Chapter 6 Entropy 195

- 6.1 Clausius Inequality 195
- 6.2 Definition Of Entropy Change 197
- 6.3 Entropy of a Pure, Simple Compressible Substance 199
- 6.4 Entropy Change in Internally Reversible Processes 207
- 6.5 Entropy Balance for Closed Systems 211
- 6.6 Entropy Rate Balance for Control Volumes 224
- 6.7 Isentropic Processes 230
- 6.8 Isentropic Efficiencies of Turbines, Nozzles, Compressors, and Pumps 237
- 6.9 Heat Transfer and Work in Internally Reversible, Steady-State Flow Processes 246

## Chapter 7 Availability (Exergy) Analysis 265

- 7.1 Introduction 265
- 7.2 Availability 266
- 7.3 Availability Balance for Closed Systems 275
- 7.4 Flow Availability 286
- 7.5 Availability Rate Balance for Control Volumes 289
- 7.6 Second Law (Exergetic) Efficiency 295
- 7.7 Thermoeconomics 303

## Chapter 8 Vapour Power Systems 316

- 8.1 Preliminaries 317
- 8.2 Rankine Cycle 318
- 8.3 Superheat and Reheat 331
- 8.4 Regenerative Vapour Power Cycle 337
- 8.5 Working Fluid Characteristics, Binary Vapour Cycles, and Cogeneration 348
- 8.6 Case Study: Availability Analysis of a Vapour Power Plant 350

## Chapter 9 Gas Power Systems 366

- 9.1 Preliminaries 367
- 9.2 Air-Standard Otto Cycle 369
- 9.3 Air-Standard Diesel Cycle 374
- 9.4 Air-Standard Dual Cycle 379
- 9.5 Preliminaries 383
- 9.6 Air-Standard Brayton Cycle 384
- 9.7 Regenerative Gas Turbines 395
- 9.8 Regenerative Gas Turbines with Reheat and Intercooling 399
- 9.9 Gas Turbines for Aircraft Propulsion 411
- 9.10 Combined Gas Turbine-Vapour Power Cycle 416
- 9.11 Ericsson and Stirling Cycles 417
- 9.12 Preliminaries 419

- 9.13 One-Dimensional Steady Flow in Nozzles and Diffusers 423  
 9.14 Flow in Nozzles and Diffusers of Ideal Gases with Constant Specific Heats 430

## Chapter 10 Refrigeration and Heat Pump Systems 447

- 10.1 Preliminaries 447  
 10.2 Vapour-Compression Refrigeration 450  
 10.3 Refrigerant Properties 459  
 10.4 Cascade and Multistage Vapour-Compression Systems 460  
 10.5 Absorption Refrigeration 462  
 10.6 Heat Pump Systems 464  
 10.7 Gas Refrigeration Systems 467

## Chapter 11.1 Thermodynamic Relations for Simple Compressible Substances 479

- 11.1 Equations of State 479  
 11.2 Thermodynamic Functions of Two Independent Variables 486  
 11.3 Relations from Exact Differentials 490  
 11.4 Some Thermodynamic Relations Involving Entropy, Internal Energy, and Enthalpy 495  
 11.5 Other Thermodynamic Relations 505  
 11.6 Constructing Tables of Thermodynamic Properties 511  
 11.7 Generalized Charts for Enthalpy and Entropy 516  
 11.8  $P$ - $v$ - $T$  Relations for Gas Mixtures 523  
 11.9 Multicomponent Systems 529

## Chapter 12 Nonreacting Ideal Gas Mixtures and Psychrometrics 551

- 12.1 Describing Mixture Composition 552  
 12.2  $P$ - $v$ - $T$  Relationships for Ideal Gas Mixtures 556  
 12.3  $U$ ,  $H$ , and  $S$  for Ideal Gas Mixtures 558  
 12.4 Mixture Processes at Constant Composition 561  
 12.5 Mixing of Ideal Gases 568  
 12.6 Introductory Psychrometric Principles 576  
 12.7 Conservation of Mass and Conservation of Energy Applied to Psychrometric Systems 585  
 12.8 Adiabatic-Saturation and Wet-Bulb Temperatures 591  
 12.9 Psychrometric Charts 595  
 12.10 Psychrometric Applications 597

## Chapter 13 Reacting Mixtures and Combustion 620

- 13.1 Combustion Process 620  
 13.2 Conservation of Energy for Reacting Systems 629  
 13.3 Adiabatic Flame Temperature 643  
 13.4 Absolute Entropy and the Third Law of Thermodynamics 646  
 13.5 Fuel Cells 653  
 13.6 Chemical Availability 654  
 13.7 Second Law (Exergetic) Efficiencies of Reacting Systems 667

<b>Chapter 14</b>	<b>Chemical and Phase Equilibrium</b>	<b>679</b>
14.1	Preliminary Considerations	679
14.2	Equation of Reaction Equilibrium	684
14.3	Calculation of Equilibrium Compositions	686
14.4	Further Examples of the Use of the Equilibrium Constant	696
14.5	Equilibrium Between Two Phases of a Pure Substance	705
14.6	Equilibrium of Multicomponent, Multiphase Systems	706
<b>Appendix</b>	<b>Tables, Figures, and Charts</b>	<b>719</b>
	Index to Tables	719
	Index to Figures and Charts	774
	<b>Symbols</b>	<b>785</b>
	<b>Answers to Selected Problems</b>	<b>787</b>
	<b>Index</b>	<b>791</b>