Contents

PREFACE xiii

	NOMENCLATURE xvii	
1	BASIC PROPERTIES AND CONCEPTS	1
	 1.1 Energy and Thermodynamics 1 1.2 Volume 5 1.3 Pressure 6 1.4 Temperature 16 1.5 Ideal Gas Law 20 1.6 Some Thermodynamic Definitions 27 1.7 Thermodynamic Processes 29 1.8 Summary 35 Problems 35 	
2	WORK AND HEAT 39	
	 2.1 Work 39 2.2 Thermodynamic Work 40 2.3 Work in a Compressible System 48 2.4 Useful and Nonuseful Work 57 2.5 Heat 62 2.6 Summary 65 Problems 67 	

વ		IRST LAW OF THERMODYNAMICS—
	3.2 En 3.3 Th 3.4 In 3.5 Ac 3.6 Cy 3.7 Su	troduction 72 tergy of a System 73 te First Law of Thermodynamics 73 ternal Energy 81 diabatic Process 89 relic Process 100 mmary 110 oblems 112
4		MODYNAMIC PROPERTIES OF PURE SUBSTANCES EQUATIONS OF STATE 117
	4.2 Lie 4.3 Th 4.4 So 4.5 Cc 4.6 Th 4.7 Ec 4.8 Su	troduction 117 quid and Vapor Phases 118 he First Law and Liquid and Vapor Phases 131 hid and Liquid Phases 143 hefficients of Isothermal Compressibility and Isobaric Expansion 149 he Compressibility Factor 151 he Compressibility Factor 156 hmmary 160 hobbems 161
5	OPEN	SYSTEMS AND THE FIRST LAW 164
	5.2 C 5.3 C 5.4 F 5.5 E 5.6 A 5.7 T 5.8 F 5.9 E 5.10 S	Control Volume 164 Conservation of Mass and Control Volume 168 Clow Work and Transfer of Energy Across Control Surface 171 Conergy Equation for a Control Volume 174 Capplications of the Steady-Flow Energy Equation 178 Chrottle Valve and Joule-Thomson Coefficient 192 Curther Applications of the Energy Equation 196 Conergy Equation for Unsteady Flow Processes 207 Commany 209 Croblems 211

- -111

Contents ix

6	THE SECOND LAW OF THERMODYNAMICS AND ENTROPY 218				AMICS
	6.1	Introduction		raible Processes	210

- 6.2 Reversible and Irreversible Processes 219 6.3 223
- The Second Law of Thermodynamics
- 6.4 Clausius Inequality 230
- 6.5 Entropy 233
- 6.6 Entropy Change for Ideal Gas 249
- 6.7 Entropy Change for a Control Volume 257
- 6.8 Available Work 261
- 6.9 Availability 277
- 6.10 Summary 280 **Problems** 281

7 ENERGY CONVERSION—GAS CYCLES

- 7.1 Introduction 286
- 7.2 Nomenclature for a Reciprocating Device
- 7.3 Reciprocating Compressor 288
- 7.4 Gas Power Cycles—Otto Cycle 297
- 7.5 The Diesel Cycle 309
- 7.6 The Dual Cycle 317
- 7.7 The Stirling Cycle 318
- 7.8 The Ericsson Cycle 322
- 7.9 322 The Atkinson Cycle
- 7.10 The Brayton Cycle 323
- 7.11 Summary 341
 - Problems 341

8 **ENERGY CONVERSION—VAPOR CYCLES** 348

- 8.1 Introduction 348
- 8.2 Mollier Diagram 349
- 8.3 The Rankine Cycle 350
- 8.4 Refrigeration 389
- 8.5 Summary 409

Problems 410

9	GENERAL	THERMODYNAMIC	DEL ATIONS	417
•	GLIVENAL	THENIVIOUTINAIVIIC	RELATIONS	41/

- 9.1 Introduction 417
- 9.2 Partial Derivatives 418
- 9.3 Maxwell Relations 421
- 9.4 The Clapeyron Equation 424
- 9.5 Thermodynamic Relations for Internal Energy, Enthalpy, and Entropy
- 9.6 Relations for c_n and c_n 430
- 9.7 Joule-Thomson Coefficient 434
- **9.8** Summary 435 Problems 436

10 NONREACTING MIXTURES 438

- 10.1 Introduction 438
- 10.2 Mixtures of Ideal Gases 439
- 10.3 Properties of Moist Air 446
- 10.4 Air Conditioning 457
- 10.5 Chemical Potential and Gibbs Function 459
- 10.6 Solutions 461
- 10.7 Summary 465
 - Problems 466

11 CHEMICAL REACTIONS AND EQUILIBRIUM 471

- **11.1** Introduction 471
- 11.2 Fuels 472
- 11.3 The Combustion Process 474
- 11.4 Chemical Reaction and the First Law 481
- 11.5 The Third Law of Thermodynamics and Absolute Entropy 495
- 11.6 Chemical Reactions and the Second Law 498
- 11.7 Equilibrium 502
- **11.8** Summary 513 Problems 514

Contents

ANSWERS TO SELECTED PROBLEMS 522

APPENDICES	525
APPENDIX A	PROPERTIES OF SOME IDEAL GASES AT 300 K 526
APPENDIX B1	PROPERTIES OF COMPRESSED LIQUID WATER 527
APPENDIX B2.1	PROPERTIES OF SATURATED STEAM
	(TEMPERATURE TABLE) 529
APPENDIX B2.2	PROPERTIES OF SATURATED STEAM
	(PRESSURE TABLE) 532
APPENDIX B3	PROPERTIES OF SUPERHEATED STEAM 535
APPENDIX B4	PROPERTIES OF WATER IN THE SATURATED
	SOLID-VAPOR REGION 543
APPENDIX C1	PROPERTIES OF FREON-12
	(DICHLORODIFLUOROMETHANE) 544
APPENDIX C2	PROPERTIES OF SUPERHEATED FREON-12 546
APPENDIX D1	PROPERTIES OF SATURATED AMMONIA 550
APPENDIX D2	PROPERTIES OF SUPERHEATED AMMONIA 552
APPENDIX E	PROPERTIES OF SATURATED MERCURY 554
APPENDIX F1	PROPERTIES OF SATURATED NITROGEN 556
APPENDIX F2	PROPERTIES OF SUPERHEATED NITROGEN 557
APPENDIX G1	PROPERTIES OF SATURATED OXYGEN 559
APPENDIX G2	PROPERTIES OF SUPERHEATED OXYGEN 560
APPENDIX H	CONSTANT-PRESSURE SPECIFIC HEATS OF
	VARIOUS IDEAL GASES 562
APPENDIX II	ENTHALPY OF FORMATION AT 25°C, IDEAL
	GAS ENTHALPY AND ABSOLUTE ENTROPY
	AT 100 kPa PRESSURE 563
APPENDIX 12	PROPERTIES OF AIR AT LOW PRESSURE 569
APPENDIX J1(a)	TEMPERATURE-ENTROPY DIAGRAM FOR H ₂ O 572
APPENDIX J1(b)	MOLLIER DIAGRAM FOR STEAM 573
APPENDIX J2	THE PRESSURE-ENTHALPY DIAGRAM FOR
	FREON-12 574
APPENDIX K	PSYCHROMETRIC CHART 575
APPENDIX L	CRITICAL CONSTANTS OF SEVERAL SUBSTANCES 576
APPENDIX M	LOGARITHMS TO THE BASE e OF THE EQUILIBRIUM
	CONSTANT K 577