

Contents

<i>Preface</i>	xiii
Part I Elements of Thermal Physics	1
1. Fundamentals	3
1.1 <i>PVT</i> Systems	3
1.2 Equilibrium States	6
1.3 Processes and Heat	10
1.4 Temperature	12
1.5 Size Dependence	13
1.6 Heat Capacity and Specific Heat Problems	14 17
2. First Law of Thermodynamics	19
2.1 Work	19
2.2 Heat	21
2.3 The First Law	21
2.4 Applications Problems	22 26
3. Properties and Partial Derivatives	27
3.1 Conventions	27
3.2 Equilibrium Properties	28
3.3 Relationships between Properties	34
3.4 Series Expansions	40
3.5 Summary Problems	41 42
4. Processes in Gases	45
4.1 Ideal Gases	45
4.2 Temperature Change with Elevation	48
4.3 Cyclic Processes	50
4.4 Heat Engines Problems	52 58
5. Phase Transitions	61
5.1 Solids, Liquids, and Gases	61
5.2 Latent Heats	65

5.3	Van der Waals Model	67
5.4	Classification of Phase Transitions Problems	70 72
6.	Reversible and Irreversible Processes	75
6.1	Idealization and Reversibility	75
6.2	Nonequilibrium Processes and Irreversibility	76
6.3	Electrical Systems	79
6.4	Heat Conduction Problems	82 86
Part II Foundations of Thermodynamics		89
7.	Second Law of Thermodynamics	91
7.1	Energy, Heat, and Reversibility	91
7.2	Cyclic Processes	93
7.3	Second Law of Thermodynamics	95
7.4	Carnot Cycles	98
7.5	Absolute Temperature	100
7.6	Applications Problems	103 107
8.	Temperature Scales and Absolute Zero	109
8.1	Temperature Scales	109
8.2	Uniform Scales and Absolute Zero	111
8.3	Other Temperature Scales Problems	114 115
9.	State Space and Differentials	117
9.1	Spaces	117
9.2	Differentials	121
9.3	Exact Versus Inexact Differentials	123
9.4	Integrating Differentials	127
9.5	Differentials in Thermodynamics	129
9.6	Discussion and Summary Problems	134 136
10.	Entropy	139
10.1	Definition of Entropy	139
10.2	Clausius' Theorem	142
10.3	Entropy Principle	145
10.4	Entropy and Irreversibility	148
10.5	Useful Energy	151
10.6	The Third Law	155
10.7	Unattainability of Absolute Zero Problems	156 158
	Appendix 10.A. Entropy Statement of the Second Law	158

11. Consequences of Existence of Entropy	165
11.1 Differentials of Entropy and Energy	165
11.2 Ideal Gases	167
11.3 Relationships Between C_V , C_p , B_T , B_S , and α_V	170
11.4 Clapeyron's Equation	172
11.5 Maximum Entropy, Equilibrium, and Stability	174
11.6 Mixing	178
Problems	184
12. Thermodynamic Potentials	185
12.1 Internal Energy	185
12.2 Free Energies	186
12.3 Properties From Potentials	188
12.4 Systems in Contact with a Heat Reservoir	193
12.5 Minimum Free Energy	194
Problems	197
Appendix 12.A. Derivatives of Potentials	197
13. Phase Transitions and Open Systems	201
13.1 Two-Phase Equilibrium	201
13.2 Chemical Potential	206
13.3 Multi-Component Systems	211
13.4 Gibbs Phase Rule	214
13.5 Chemical Reactions	215
Problems	217
14. Dielectric and Magnetic Systems	219
14.1 Dielectrics	219
14.2 Magnetic Materials	224
14.3 Critical Phenomena	229
Problems	233
Part III Statistical Thermodynamics	235
15. Molecular Models	237
15.1 Microscopic Descriptions	237
15.2 Gas Pressure	238
15.3 Equipartition of Energy	243
15.4 Internal Energy of Solids	246
15.5 Inactive Degrees of Freedom	247
15.6 Microscopic Significance of Heat	248
Problems	253
16. Kinetic Theory of Gases	255
16.1 Velocity Distribution	255
16.2 Combinatorics	256
16.3 Method of Undetermined Multipliers	258

16.4	Maxwell Distribution	260
16.5	Mean-Free-Path	265
	Problems	267
	Appendix 16.A. Quantum Distributions	267
17.	Microscopic Significance of Entropy	273
17.1	Boltzmann Entropy	273
17.2	Ideal Gas	274
17.3	Statistical Interpretation	278
17.4	Thermodynamic Properties	279
17.5	Boltzmann Factors	284
	Problems	286
	Appendix 17.A. Evaluation of I_{3N}	286
Part IV	Statistical Mechanics I	289
18.	Ensembles	291
18.1	Probabilities and Averages	291
18.2	Two-Level Systems	293
18.3	Information Theory	295
18.4	Equilibrium Ensembles	298
18.5	Canonical Thermodynamics	302
18.6	Composite Systems	305
	Problems	308
	Appendix 18.A. Uniqueness Theorem	308
19.	Partition Function	311
19.1	Hamiltonians and Phase Space	311
19.2	Model Hamiltonians	312
19.3	Classical Canonical Ensemble	316
19.4	Thermodynamic Properties and Averages	318
19.5	Ideal Gases	322
19.6	Harmonic Solids	326
	Problems	328
20.	Quantum Systems	331
20.1	Energy Eigenstates	331
20.2	Quantum Canonical Ensemble	333
20.3	Ideal Gases	334
20.4	Einstein Model	337
20.5	Classical Approximation	341
	Problems	344
	Appendix 20.A. Ideal Gas Eigenstates	344
21.	Independent Particles and Paramagnetism	349
21.1	Averages	349

21.2	Statistical Independence	351
21.3	Classical Systems	353
21.4	Paramagnetism	357
21.5	Spin Systems	360
21.6	Classical Dipoles	365
	Problems	367
	Appendix 21.A. Negative Temperature	367
22.	Fluctuations and Energy Distributions	371
22.1	Standard Deviation	371
22.2	Energy Fluctuations	375
22.3	Gibbs Paradox	376
22.4	Microcanonical Ensemble	380
22.5	Comparison of Ensembles	386
	Problems	391
23.	Generalizations and Diatomic Gases	393
23.1	Generalized Coordinates	393
23.2	Diatomic Gases	397
23.3	Quantum Effects	402
23.4	Density Matrices	405
23.5	Canonical Ensemble	408
	Problems	410
	Appendix 23.A. Classical Approximation	410
Part V	Statistical Mechanics II	415
24.	Photons and Phonons	417
24.1	Plane Wave Eigenstates	417
24.2	Photons	421
24.3	Harmonic Approximation	425
24.4	Phonons	429
	Problems	434
25.	Grand Canonical Ensemble	435
25.1	Thermodynamics of Open Systems	435
25.2	Grand Canonical Ensemble	437
25.3	Properties and Fluctuations	438
25.4	Ideal Gases	441
	Problems	443
26.	Fermions and Bosons	445
26.1	Identical Particles	445
26.2	Exchange Symmetry	447
26.3	Fermi–Dirac and Bose–Einstein Statistics	452
	Problems	456
	Appendix 26.A. Fermions in the Canonical Ensemble	457

27. Fermi and Bose Gases	461
27.1 Ideal Gases	461
27.2 Fermi Gases	465
27.3 Low Temperature Heat Capacity	466
27.4 Bose Gases	469
Problems	472
28. Interacting Systems	475
28.1 Ising Model	475
28.2 Nonideal Gases	481
Problems	487
29. Computer Simulations	489
29.1 Averages	489
29.2 Virial Formula for Pressure	490
29.3 Simulation Algorithms	496
A. Mathematical Relations, Constants, and Properties	501
A.1 Partial Derivatives	501
A.2 Integrals and Series	501
A.3 Taylor Series	502
A.4 Hyperbolic Functions	502
A.5 Fundamental Constants	503
A.6 Conversion Factors	503
A.7 Useful Formulas	503
A.8 Properties of Water	504
A.9 Properties of Materials	504
<i>Answers to Problems</i>	505
<i>Index</i>	509