

# Contents

Preface . . . . .	vii
-------------------	-----

## Part I: Fundamentals

→ Chapter 1 Energy in Thermal Physics . . . . .	1
1.1 Thermal Equilibrium . . . . .	1
1.2 The Ideal Gas . . . . .	6
<i>Microscopic Model of an Ideal Gas</i>	
1.3 Equipartition of Energy . . . . .	14
1.4 Heat and Work . . . . .	17
1.5 Compression Work . . . . .	20
<i>Compression of an Ideal Gas</i>	
1.6 Heat Capacities . . . . .	28
<i>Latent Heat; Enthalpy</i>	
<del>    1.7 Rates of Processes . . . . .</del>	<del>37</del>
<del>        <i>Heat Conduction; Conductivity of an Ideal Gas;</i></del>	
<del>        <i>Viscosity; Diffusion</i></del>	
→ Chapter 2 The Second Law . . . . .	49
2.1 Two-State Systems . . . . .	49
<i>The Two-State Paramagnet</i>	
2.2 The Einstein Model of a Solid . . . . .	53
2.3 Interacting Systems . . . . .	56
2.4 Large Systems . . . . .	60
<i>Very Large Numbers; Stirling's Approximation;</i>	
<i>Multiplicity of a Large Einstein Solid;</i>	
<i>Sharpness of the Multiplicity Function</i>	
2.5 The Ideal Gas . . . . .	68
<i>Multiplicity of a Monatomic Ideal Gas;</i>	
<i>Interacting Ideal Gases</i>	
2.6 Entropy . . . . .	74
<i>Entropy of an Ideal Gas; Entropy of Mixing;</i>	
<i>Reversible and Irreversible Processes</i>	

→ **Chapter 3 Interactions and Implications . . . . . 85**

3.1 Temperature . . . . . 85  
*A Silly Analogy; Real-World Examples*

3.2 Entropy and Heat . . . . . 92  
*Predicting Heat Capacities; Measuring Entropies;  
 The Macroscopic View of Entropy*

3.3 Paramagnetism . . . . . 98  
*Notation and Microscopic Physics; Numerical Solution;  
 Analytic Solution*

3.4 Mechanical Equilibrium and Pressure . . . . . 108  
*The Thermodynamic Identity; Entropy and Heat Revisited*

3.5 Diffusive Equilibrium and Chemical Potential . . . . . 115

3.6 Summary and a Look Ahead . . . . . 120

Part II: Thermodynamics

**Chapter 4 Engines and Refrigerators . . . . . 122**

→ 4.1 Heat Engines . . . . . 122  
*The Carnot Cycle*

→ 4.2 Refrigerators . . . . . 127

4.3 Real Heat Engines . . . . . 131  
*Internal Combustion Engines; The Steam Engine*

4.4 Real Refrigerators . . . . . 137  
*The Throttling Process; Liquefaction of Gases;  
 Toward Absolute Zero*

**Chapter 5 Free Energy and Chemical Thermodynamics . . . . . 149**

→ 5.1 Free Energy as Available Work . . . . . 149  
*Electrolysis, Fuel Cells, and Batteries;  
 Thermodynamic Identities*

→ 5.2 Free Energy as a Force toward Equilibrium . . . . . 161  
*Extensive and Intensive Quantities; Gibbs Free Energy  
 and Chemical Potential*

→ 5.4 Phase Transformations of Pure Substances . . . . . 166  
*Diamonds and Graphite; The Clausius-Clapeyron  
 Relation; The van der Waals Model*

5.4 Phase Transformations of Mixtures . . . . . 186  
*Free Energy of a Mixture; Phase Changes of a Miscible  
 Mixture; Phase Changes of a Eutectic System*

5.5 Dilute Solutions . . . . . 200  
*Solvent and Solute Chemical Potentials; Osmotic Pressure;  
 Boiling and Freezing Points*

5.6 Chemical Equilibrium . . . . . 208  
*Nitrogen Fixation; Dissociation of Water; Oxygen  
 Dissolving in Water; Ionization of Hydrogen*

Part III: Statistical Mechanics

→ **Chapter 6 Boltzmann Statistics . . . . . 220**

6.1 The Boltzmann Factor . . . . . 220  
*The Partition Function; Thermal Excitation of Atoms*

6.2 Average Values . . . . . 229  
*Paramagnetism; Rotation of Diatomic Molecules*

6.3 The Equipartition Theorem . . . . . 238

6.4 The Maxwell Speed Distribution . . . . . 242

6.5 Partition Functions and Free Energy . . . . . 247

6.6 Partition Functions for Composite Systems . . . . . 249

6.7 Ideal Gas Revisited . . . . . 251  
*The Partition Function; Predictions*

**Chapter 7 Quantum Statistics . . . . . 257**

→ 7.1 The Gibbs Factor . . . . . 257  
*An Example: Carbon Monoxide Poisoning*

→ 7.2 Bosons and Fermions . . . . . 262  
*The Distribution Functions*

7.3 Degenerate Fermi Gases . . . . . 271  
*Zero Temperature; Small Nonzero Temperatures;  
 The Density of States; The Sommerfeld Expansion*

7.4 Blackbody Radiation . . . . . 288  
*The Ultraviolet Catastrophe; The Planck Distribution;  
 Photons; Summing over Modes; The Planck Spectrum;  
 Total Energy; Entropy of a Photon Gas; The Cosmic  
 Background Radiation; Photons Escaping through a Hole;  
 Radiation from Other Objects; The Sun and the Earth*

7.5 Debye Theory of Solids . . . . . 307

7.6 Bose-Einstein Condensation . . . . . 315  
*Real-World Examples; Why Does it Happen?*

**Chapter 8 Systems of Interacting Particles . . . . . 327**

8.1 Weakly Interacting Gases . . . . . 328  
*The Partition Function; The Cluster Expansion;  
 The Second Virial Coefficient*

8.2 The Ising Model of a Ferromagnet . . . . . 339  
*Exact Solution in One Dimension;  
 The Mean Field Approximation;  
 Monte Carlo Simulation*

\* \* \*

<b>Appendix A Elements of Quantum Mechanics . . . . .</b>	<b>357</b>
A.1 Evidence for Wave-Particle Duality . . . . .	357
<i>The Photoelectric Effect; Electron Diffraction</i>	
A.2 Wavefunctions . . . . .	362
<i>The Uncertainty Principle; Linearly Independent Wavefunctions</i>	
A.3 Definite-Energy Wavefunctions . . . . .	367
<i>The Particle in a Box; The Harmonic Oscillator; The Hydrogen Atom</i>	
A.4 Angular Momentum . . . . .	374
<i>Rotating Molecules; Spin</i>	
A.5 Systems of Many Particles . . . . .	379
A.6 Quantum Field Theory . . . . .	380
<b>Appendix B Mathematical Results . . . . .</b>	<b>384</b>
B.1 Gaussian Integrals . . . . .	384
B.2 The Gamma Function . . . . .	387
B.3 Stirling’s Approximation . . . . .	389
B.4 Area of a <i>d</i> -Dimensional Hypersphere . . . . .	391
B.5 Integrals of Quantum Statistics . . . . .	393
<b>Suggested Reading . . . . .</b>	<b>397</b>
<b>Reference Data . . . . .</b>	<b>402</b>
<b>Index . . . . .</b>	<b>406</b>