

Contents

	<i>Preface</i>	<i>page xi</i>
1	Introduction	1
2	Thermodynamics	16
	2.1 The experience of asymmetry in time	16
	2.2 The Law of Conservation of Energy	18
	2.3 The Law of Approach to Equilibrium	22
	2.4 The Second Law of Thermodynamics	25
	2.5 The status of the laws of thermodynamics	38
3	Classical mechanics	40
	3.1 The fundamental theory of the world	40
	3.2 Introducing classical mechanics	42
	3.3 Mechanical states	43
	3.4 Time evolution of mechanical states	49
	3.5 Thermodynamic magnitudes	51
	3.6 A mechanical no-go theorem	56
	3.7 The ergodic approach	62
	3.8 Conclusion	71
4	Time	72
	4.1 Introduction: why mechanics cannot underwrite thermodynamics	72
	4.2 Classical kinematics	73
	4.3 The direction of time and the direction of velocity in time	74
	4.4 The description of mechanical states	76
	4.5 Velocity reversal	80

viii	<i>Contents</i>	
	4.6 Retrodiction	84
	4.7 Time reversal and time-reversal invariance	86
	4.8 Why the time-reversal invariance of classical mechanics matters	91
5	Macrostates	94
	5.1 The physical nature of macrostates	94
	5.2 How do macrostates come about?	97
	5.3 Explaining thermodynamics with macrostates	105
	5.4 The dynamics of macrostates	106
	5.5 The physical origin of thermodynamic macrostates	108
	5.6 Boltzmann’s macrostates	111
	5.7 Maxwell–Boltzmann distribution	115
	5.8 The observer in statistical mechanics	119
	5.9 Counterfactual observers	123
6	Probability	125
	6.1 Introduction	125
	6.2 Probability in statistical mechanics	126
	6.3 Choice of measure in statistical mechanics	132
	6.4 Measure of a macrostate and its probability	136
	6.5 Transition probabilities without blobs	137
	6.6 Dependence on observed history?	139
	6.7 The spin echo experiments	143
	6.8 Robustness of transition probabilities	149
	6.9 No probability over initial conditions	149
7	Entropy	153
	7.1 Introduction	153
	7.2 Entropy	154
	7.3 The distinction between entropy and probability	158
	7.4 Equilibrium in statistical mechanics	159
	7.5 Law of Approach to Equilibrium	160
	7.6 Second Law of Thermodynamics	162
	7.7 Boltzmann’s <i>H</i> -theorem	164
	7.8 Loschmidt’s reversibility objection	167
	7.9 Poincaré’s recurrence theorem	170
	7.10 Boltzmann’s combinatorial argument	171
	7.11 Back to Boltzmann’s equation: Lanford’s theorem	175
	7.12 Conclusion	178

	<i>Contents</i>	ix
8	Typicality	182
	8.1 Introduction	182
	8.2 The explanatory arrow in statistical mechanics	183
	8.3 Typicality	184
	8.4 Are there natural measures?	186
	8.5 Typical initial conditions	187
	8.6 Measure-1 theorems and typicality	189
	8.7 Conclusion	191
9	Measurement	192
	9.1 Introduction	192
	9.2 What is measurement in classical mechanics?	193
	9.3 Collapse in classical measurement	200
	9.4 State preparation	202
	9.5 The shadows approach	206
	9.6 Entropy	207
	9.7 Status of the observer	209
10	The past	212
	10.1 Introduction	212
	10.2 The problem of retrodiction	213
	10.3 The Past Hypothesis: memory and measurement	216
	10.4 The Reliability Hypothesis	219
	10.5 Past low entropy hypothesis	222
	10.6 Remembering the future	224
	10.7 Problem of initial improbable state	226
	10.8 The dynamics of the Past Hypothesis	228
	10.9 Local and global Past Hypotheses	229
	10.10 Past Hypothesis and physics of memory	230
	10.11 Memory in a time-reversed universe	232
11	Gibbs	234
	11.1 Introduction	234
	11.2 The Gibbsian method in equilibrium	235
	11.3 Gibbsian method in terms of blobs and macrostates	238
	11.4 Gibbsian equilibrium probability distributions	240
	11.5 The approach to equilibrium	241

x	<i>Contents</i>	
12	Erasure	246
12.1	Introduction	246
12.2	Why there is no microscopic erasure	247
12.3	What is a macroscopic erasure?	248
12.4	Necessary and sufficient conditions for erasure	251
12.5	Logic and entropy	254
12.6	Another logically irreversible operation	255
12.7	Logic and entropy: a model	257
12.8	What does erasure erase?	268
12.9	Conclusion	268
13	Maxwell’s Demon	270
13.1	Thermodynamic and statistical mechanical demons	270
13.2	Szilard’s insight	273
13.3	Entropy reduction: measurement	273
13.4	Efficiency and predictability	278
13.5	Completing the cycle of operation: erasure	280
13.6	The Liberal Stance	284
13.7	Conclusion	286
Appendix A	Szilard’s engine	288
Appendix B	Quantum mechanics	300
B.1	Albert’s approach	301
B.2	Bohmian mechanics	307
B.3	A quantum mechanical Maxwellian Demon	309
	<i>References</i>	319
	<i>Index</i>	326