CONTENTS

1. BASIC THERMODYNAMIC CONCEPTS AND LAWS 1

Definitions, 1
Closed Systems, 2
Open Systems, 7
The Momentum Theorem, 14
Useful Steps in Problem Solving, 15
Symbols, 16
Selected Readings, 16
Problems, 17

2. ENTROPY GENERATION AND LOST AVAILABLE WORK 21

The Gouy–Stodola Theorem, 21
Systems Communicating with More Than One Heat Reservoir, 24
Adiabatic Systems, 28
Availability (Exergy) Analysis of Steady Flow Processes, 29
Availability vs. Exergy: A Historical Perspective, 32
Steady Flow vs. Nonflow Availability and Exergy, 33
Characteristic Features of Irreversible Systems and Processes, 35
Symbols, 42
References, 42
Problems, 44

3. VISCOUS DISSIPATION IN FLUID FLOW 48

Relationship between Entropy Generation and Viscous Dissipation, 48

The Laminar Regime, 50
The Turbulent Regime, 52
The Transition, 59
The Viscid–Inviscid Transition, 61
Symbols, 62
References, 63

4. THEORY OF TURBULENT FLOW **64**

Empiricism vs. Theory in Turbulence Research, 65
The Sinuous Course of High Reynolds Number Streams, 67
The Buckling Property of Inviscid Streams, 70
Mechanism of Eddy Formation and Jet Growth, 74
Transition to Turbulence: The Buckling Number, 77
Buckled Wakes: The Origin of "Vortex Shedding", 79
The Fibrous Structure of the Inviscid Flow, 80
The Rolling of Buckled Shear Layers, 82
Transition to Turbulence in Shear Flow: The Smallest Eddy, 85
Periodic Bursting of Wall Shear Layers, 87
Laboratory Visualization of the Buckling Property, 90
Symbols, 94
References, 95

5. CONVECTIVE HEAT TRANSFER **98**

Local Rate of Entropy Generation, 99
Fluid Friction vs. Heat Transfer Irreversibility, 102
Internal Flows, 105
External Flows, 109
Symbols, 114
References, 115
Problems, 116

6. HEAT TRANSFER AUGMENTATION TECHNIQUES **118**

Entropy Generation Analysis, 119
Roughened Surfaces, 120
Promoters of Swirl Flow, 125
Extended Surfaces (Fins), 127
Symbols, 132
References, 134

7. HEAT EXCHANGERS 135

Counterflow Heat Exchangers, 135
Balanced Counterflow, 138
Optimum Flow Path Length, 141
Irreversibility Minimization Subject to Constraints, 142
Distribution of Heat Exchanger Area on the Absolute Temperature Scale, 145
Distribution of Heat Transfer Area in Counterflow Heat Exchangers, 151
Symbols, 153
References, 154
Problems, 155

8. THERMAL ENERGY STORAGE 158

Transient Operation of Storage Elements, 158
Destruction of Exergy during Energy Storage, 160
Series of Storage Units, 165
Optimum Flow Rate History, 166
Energy Storage vs. Refrigeration Storage, 169
Symbols, 171
References, 171

9. THERMAL INSULATION SYSTEMS 173

Irreversibility of Insulation with Fixed Geometry, 174
Optimum Continuous Cooling Regime, 177
Counterflow Heat Exchangers As One-Dimensional Insulations, 180
Parallel Insulations, 182
Symbols, 186
References, 186
Problems, 186

10. LOW TEMPERATURE APPLICATIONS 188

Mechanical Supports, 188
Insulations Cooled with Helium Boil-off, 192
Radiation Shields, 197
Electric Cables, 199
Helium Refrigeration Cycles, 201

Symbols, 203
References, 204

11. SOLAR ENERGY **206**

The Exergy Content of Thermal Radiation, 206
The Exergy of Sunlight, 209
Exergy Waste in Solar Collectors, 211
Isothermal Collectors, 214
Nonisothermal Collectors, 216
Time-varying Conditions, 220
Operation at Constant Collector Temperature, 224
Symbols, 227
References, 228
Problems, 229

12. ENERGY POLICY by Mary Bejan **231**

The Application of Entropy Generation Minimization Principles, 231
End-Use Matching: The Demand-side View, 232
Policy Implications of Incorporating a Supply-side Perspective, 233
Solar Exergy: A High Temperature Fuel, 237
The Effect of User Density on the Ability to Extract Exergy, 238
Conclusion, 239
References, 240

APPENDIX A. LOCAL ENTROPY GENERATION RATE **241**

APPENDIX B. VARIATIONAL CALCULUS **243**

INDEX **245**