



# Contents

|          |   |     |
|----------|---|-----|
| <b>1</b> | <b>Introduction</b>                                       | 1   |
| <b>2</b> | <b>How to Measure the Temperature</b>                     | 5   |
| 2.1      | Thermoscopes and Thermometers                             | 5   |
| 2.2      | Spectral Temperature                                      | 12  |
| 2.3      | Chemical Temperature                                      | 23  |
|          | Problems  | 27  |
| <b>3</b> | <b>How to Interpret the Temperature</b>                   | 29  |
| 3.1      | The Temperature as an Equilibrium Parameter               | 30  |
| 3.2      | The Temperature Related to an Integrating Factor          | 46  |
| 3.3      | The Temperature Related to a Lagrange Multiplier          | 53  |
| 3.4      | The Temperature as a Property of the Noise                | 60  |
|          | Problems  | 70  |
| <b>4</b> | <b>Fluctuating Temperature</b>                            | 73  |
| 4.1      | Microcanonical Temperature Distribution                   | 74  |
| 4.2      | Fluctuations in Finite Phase Space                        | 78  |
| 4.3      | Near-equilibrium Fluctuations                             | 86  |
| 4.4      | Superstatistics   | 89  |
| 4.5      | Canonical Enhancement                                     | 92  |
|          | Problems  | 98  |
| <b>5</b> | <b>Complications with the Temperature</b>                 | 99  |
| 5.1      | Colored and Multiplicative Noise                          | 100 |
| 5.2      | Fisher Entropy  | 115 |
| 5.3      | Thermodynamics of Abstract Composition Rules              | 120 |
|          | Problems  | 143 |
| <b>6</b> | <b>The Temperature of Moving Bodies</b>                   | 145 |
| 6.1      | Relativistic Thermodynamics                               | 146 |
| 6.2      | Disputes About the Temperature at Relativistic Velocities | 146 |

|   |            |
|---|------------|
| 6.3 Thermodynamics of Energy and Momentum Exchange .....          | 148        |
| 6.4 Relativistic Thermal Equilibrium .....                        | 157        |
| Problems .....  | 164        |
| <b>7 The Temperature of no Return .....</b>                       | <b>165</b> |
| 7.1 Temperature due to Acceleration: The Unruh Effect .....       | 166        |
| 7.2 Formal Entropy and Temperature for Black Holes .....          | 170        |
| 7.3 Quark Matter Equation of State from Dual Gravity Models ..... | 200        |
| Problems .....  | 219        |
| <b>8 The Temperature in Quantum Field Theory .....</b>            | <b>221</b> |
| 8.1 Imaginary Time Formalism .....                                | 221        |
| 8.2 Off Equilibrium Field Theory .....                            | 233        |
| 8.3 Feynman Path Integral and Canonical Partition Sum .....       | 238        |
| 8.4 Quantization due to Higher-Dimensional Chaotic Dynamics ..... | 255        |
| Problems .....  | 264        |
| <b>Afterword .....</b>  | <b>265</b> |
| <b>Solutions .....</b>  | <b>269</b> |
| <b>References .....</b>   | <b>305</b> |
| <b>Index .....</b>  | <b>309</b> |

