

Contents

| | |
|---|-----------|
| Preface | v |
| Constants, Signs, Symbols, and General Remarks | xiii |
| I Preliminaries | 1 |
| 1 Introduction | 3 |
| 1.1 Crystal Lattices | 3 |
| 1.2 Theoretical Background | 5 |
| 1.2.1 Metals and Conduction Electrons | 5 |
| 1.2.2 Quantum Mechanics | 6 |
| 1.2.3 Heisenberg Uncertainty Principle | 6 |
| 1.2.4 Bosons and Fermions | 7 |
| 1.2.5 Fermi and Bose Distribution Functions | 7 |
| 1.2.6 Composite Particles | 7 |
| 1.2.7 Quasifree Electron Model | 8 |
| 1.2.8 “Electrons” and “Holes” | 8 |
| 2 Lattice Vibrations and Heat Capacity | 11 |
| 2.1 Einstein’s Theory of Heat Capacity | 11 |
| 2.2 Debye’s Theory of Heat Capacity | 15 |
| 3 Free Electrons and Heat Capacity | 25 |
| 3.1 Free Electrons and the Fermi Energy | 25 |
| 3.2 Density of States | 30 |
| 3.3 Qualitative Discussions | 36 |
| 3.4 Quantitative Calculations | 38 |

| | | |
|-----------|---|------------|
| 4 | Electric Conduction and the Hall Effect | 43 |
| 4.1 | Ohm's Law and Matthiessen's Rule | 43 |
| 4.2 | Motion of a Charged Particle in Electromagnetic Fields | 46 |
| 4.3 | The Landau States and Levels | 48 |
| 4.4 | The Degeneracy of the Landau Levels | 51 |
| 4.5 | The Hall Effect: "Electrons" and "Holes" | 56 |
| 5 | Magnetic Susceptibility | 61 |
| 5.1 | The Magnetogyric Ratio | 61 |
| 5.2 | Pauli Paramagnetism | 64 |
| 5.3 | Landau Diamagnetism | 67 |
| 6 | Boltzmann Equation Method | 75 |
| 6.1 | The Boltzmann Equation | 75 |
| 6.2 | The Current Relaxation Rate | 78 |
| II | Bloch Electron Dynamics | 83 |
| 7 | Bloch Theorem | 85 |
| 7.1 | The Bloch Theorem | 85 |
| 7.2 | The Kronig–Penney Model | 91 |
| 8 | The Fermi Liquid Model | 97 |
| 8.1 | The Self-consistent Field Approximation | 97 |
| 8.2 | Fermi Liquid Model | 99 |
| 9 | The Fermi Surface | 103 |
| 9.1 | Monovalent Metals (Na, Cu) | 103 |
| 9.2 | Multivalent Metals | 107 |
| 9.3 | Electronic Heat Capacity and Density of States | 111 |
| 10 | Bloch Electron Dynamics | 115 |
| 10.1 | Introduction | 115 |
| 10.2 | Newtonian Equations of Motion | 117 |
| 10.3 | Discussion | 123 |

III Applications. Fermionic Systems (Electrons) 131

11 De Haas–Van Alphen Oscillations 133

- 11.1 Onsager’s Formula 133
- 11.2 Statistical Mechanical Calculations: 3D 139
- 11.3 Statistical Mechanical Calculations: 2D 142
- 11.4 Two-Dimensional Conductors 147

12 Magnetoresistance 151

- 12.1 Introduction 151
- 12.2 Anisotropic Magnetoresistance in Cu 153
- 12.3 Shubnikov–De Haas Oscillations 155
- 12.4 Heterojunction GaAs/AlGaAs 161

13 Cyclotron Resonance 171

- 13.1 Introduction 171
- 13.2 Cyclotron Resonance in Ge and Si 172
- 13.3 Cyclotron Resonance in Al 184
- 13.4 Cyclotron Resonance in Pb 188
- 13.5 Cyclotron Resonance in Zn and Cd (HCP) 192

14 Seebeck Coefficient (Thermopower) 195

- 14.1 Introduction 195
- 14.2 Quantum Theory 197
- 14.3 Discussion 200

15 Infrared Hall Effect 205

- 15.1 Introduction 205
- 15.2 Kinetic Theory 209
 - 15.2.1 Conductivity 209
 - 15.2.2 Hall Coefficient 209
 - 15.2.3 Hall Angle 210
 - 15.2.4 Dynamic Coefficients 210
- 15.3 Discussion 213

Appendix A: Electromagnetic Potentials 217

| | |
|---|------------|
| Appendix B: Statistical Weight for the Landau States | 221 |
| B.1 The Three-Dimensional Case | 221 |
| B.2 The Two-Dimensional Case | 223 |
| Appendix C: Derivation of Equation (11.19) | 225 |
| References | 227 |
| Bibliography | 233 |
| Index | 237 |

Quantum Theory of Conducting Matter

Newtonian Equations of Motion for a Bloch Electron

Fujita, S.; Ito, K.

2007, XX, 244 p. 80 illus.,

ISBN: 978-0-387-74103-1