

Contents

Preface of the First Edition *XI*

Preface of the Second Edition *XIII*

Physical Constants and Energy Equivalents *XV*

1	Crystal Structures 1
1.1	General Description of Crystal Structures 2
1.2	Some Important Crystal Structures 4
1.2.1	Cubic Structures 4
1.2.2	Close-Packed Structures 5
1.2.3	Structures of Covalently Bonded Solids 6
1.3	Crystal Structure Determination 7
1.3.1	X-Ray Diffraction 7
1.3.1.1	Bragg Theory 7
1.3.1.2	Lattice Planes and Miller Indices 8
1.3.1.3	General Diffraction Theory 9
1.3.1.4	The Reciprocal Lattice 11
1.3.1.5	The Meaning of the Reciprocal Lattice 12
1.3.1.6	X-Ray Diffraction from Periodic Structures 14
1.3.1.7	The Ewald Construction 15
1.3.1.8	Relation Between Bragg and Laue Theory 16
1.3.2	Other Methods for Structural Determination 17
1.3.3	Inelastic Scattering 17
1.4	Further Reading 18
1.5	Discussion and Problems 18
2	Bonding in Solids 23
2.1	Attractive and Repulsive Forces 23
2.2	Ionic Bonding 24
2.3	Covalent Bonding 25
2.4	Metallic Bonding 28
2.5	Hydrogen Bonding 29
2.6	van der Waals Bonding 29

2.7	Further Reading	30
2.8	Discussion and Problems	30
3	Mechanical Properties	33
3.1	Elastic Deformation	35
3.1.1	Macroscopic Picture	35
3.1.1.1	Elastic Constants	35
3.1.1.2	Poisson's Ratio	36
3.1.1.3	Relation between Elastic Constants	37
3.1.2	Microscopic Picture	37
3.2	Plastic Deformation	38
3.2.1	Estimate of the Yield Stress	39
3.2.2	Point Defects and Dislocations	41
3.2.3	The Role of Defects in Plastic Deformation	41
3.3	Fracture	43
3.4	Further Reading	44
3.5	Discussion and Problems	45
4	Thermal Properties of the Lattice	47
4.1	Lattice Vibrations	47
4.1.1	A Simple Harmonic Oscillator	47
4.1.2	An Infinite Chain of Atoms	48
4.1.2.1	One Atom Per Unit Cell	48
4.1.2.2	The First Brillouin Zone	51
4.1.2.3	Two Atoms per Unit Cell	52
4.1.3	A Finite Chain of Atoms	53
4.1.4	Quantized Vibrations, Phonons	55
4.1.5	Three-Dimensional Solids	57
4.1.5.1	Generalization to Three Dimensions	57
4.1.5.2	Estimate of the Vibrational Frequencies from the Elastic Constants	58
4.2	Heat Capacity of the Lattice	60
4.2.1	Classical Theory and Experimental Results	60
4.2.2	Einstein Model	62
4.2.3	Debye Model	63
4.3	Thermal Conductivity	67
4.4	Thermal Expansion	70
4.5	Allotropic Phase Transitions and Melting	71
4.6	References	74
4.7	Further Reading	74
4.7	Discussion and Problems	74
5	Electronic Properties of Metals: Classical Approach	77
5.1	Basic Assumptions of the Drude Model	77
5.2	Results from the Drude Model	79

5.2.1	DC Electrical Conductivity	79
5.2.2	<i>Hall Effect</i>	81
5.2.3	Optical Reflectivity of Metals	82
5.2.4	The Wiedemann–Franz Law	85
5.3	Shortcomings of the Drude Model	86
5.4	Further Reading	87
5.5	Discussion and Problems	87
6	Electronic Properties of Solids: Quantum Mechanical Approach	91
6.1	The Idea of Energy Bands	92
6.2	Free Electron Model	94
6.2.1	The Quantum Mechanical Eigenstates	94
6.2.2	Electronic Heat Capacity	99
6.2.3	The Wiedemann–Franz Law	100
6.2.4	Screening	101
6.3	The General Form of the Electronic States	103
6.4	Nearly Free Electron Model	106
6.5	Tight-binding Model	111
6.6	Energy Bands in Real Solids	116
6.7	Transport Properties	122
6.8	Brief Review of Some Key Ideas	126
6.9	References	127
6.10	Further Reading	127
6.10	Discussion and Problems	127
7	Semiconductors	131
7.1	Intrinsic Semiconductors	132
7.1.1	Temperature Dependence of the Carrier Density	134
7.2	Doped Semiconductors	139
7.2.1	n and p Doping	139
7.2.2	Carrier Density	141
7.3	Conductivity of Semiconductors	144
7.4	Semiconductor Devices	145
7.4.1	The pn Junction	145
7.4.2	Transistors	150
7.4.3	Optoelectronic Devices	151
7.5	Further Reading	155
7.6	Discussion and Problems	155
8	Magnetism	159
8.1	Macroscopic Description	159
8.2	Quantum Mechanical Description of Magnetism	161
8.3	Paramagnetism and Diamagnetism in Atoms	163
8.4	Weak Magnetism in Solids	166
8.4.1	<i>Diamagnetic Contributions</i>	167

8.4.1.1	Contribution from the Atoms	167
8.4.1.2	Contribution from the Free Electrons	167
8.4.2	Paramagnetic Contributions	168
8.4.2.1	Curie Paramagnetism	168
8.4.2.2	Pauli Paramagnetism	170
8.5	Magnetic Ordering	171
8.5.1	Magnetic Ordering and the Exchange Interaction	172
8.5.2	Magnetic Ordering for Localized Spins	174
8.5.3	Magnetic Ordering in a Band Picture	178
8.5.4	Ferromagnetic Domains	180
8.5.5	Hysteresis	181
8.6	References	182
8.7	Further Reading	183
8.7	Discussion and Problems	183
9	Dielectrics	187
9.1	Macroscopic Description	187
9.2	Microscopic Polarization	189
9.3	The Local Field	191
9.4	Frequency Dependence of the Dielectric Constant	192
9.4.1	Excitation of Lattice Vibrations	192
9.4.2	Electronic Transitions	196
9.5	Other Effects	197
9.5.1	Impurities in Dielectrics	197
9.5.2	Ferroelectricity	198
9.5.3	Piezoelectricity	199
9.5.4	Dielectric Breakdown	200
9.6	Further Reading	200
9.7	Discussion and Problems	201
10	Superconductivity	203
10.1	Basic Experimental Facts	204
10.1.1	Zero Resistivity	204
10.1.2	The Meissner Effect	207
10.1.3	The Isotope Effect	209
10.2	Some Theoretical Aspects	210
10.2.1	Phenomenological Theory	210
10.2.2	Microscopic BCS Theory	212
10.3	Experimental Detection of the Gap	218
10.4	Coherence of the Superconducting State	220
10.5	Type I and Type II Superconductors	222
10.6	High-Temperature Superconductivity	224
10.7	Concluding Remarks	226
10.7	References	227

- 10.8 Further Reading 227
10.9 Discussion and Problems 227

- 11 Finite Solids and Nanostructures 231**
11.1 Quantum Confinement 232
11.2 Surfaces and Interfaces 234
11.3 Magnetism on the Nanoscale 237
11.4 Further Reading 238
11.5 Discussion and Problems 239

Appendix A 241

- A.1 Explicit Forms of Vector Operations 241
A.2 Differential Form of the Maxwell Equations 242
A.3 Maxwell Equations in Matter 243

Index 245