

Contents

Preface to the First Edition	<i>xi</i>
Preface to the Second Edition	<i>xiii</i>
Preface to the Third Edition	<i>xv</i>
Physical Constants and Energy Equivalents	<i>xvii</i>

1	Crystal Structures	<i>1</i>
1.1	General Description of Crystal Structures	<i>2</i>
1.2	Some Important Crystal Structures	<i>3</i>
1.2.1	Cubic Structures	<i>4</i>
1.2.2	Close-Packed Structures	<i>5</i>
1.2.3	Structures of Covalently Bonded Solids	<i>6</i>
1.3	Crystal Structure Determination	<i>7</i>
1.3.1	X-Ray Diffraction	<i>7</i>
1.3.1.1	Bragg Theory	<i>7</i>
1.3.1.2	Lattice Planes and Miller Indices	<i>8</i>
1.3.1.3	General Diffraction Theory	<i>9</i>
1.3.1.4	The Reciprocal Lattice	<i>11</i>
1.3.1.5	The Meaning of the Reciprocal Lattice	<i>12</i>
1.3.1.6	X-Ray Diffraction from Periodic Structures	<i>14</i>
1.3.1.7	The Ewald Construction	<i>15</i>
1.3.1.8	Relation Between Bragg and Laue Theory	<i>16</i>
1.3.2	Other Methods for Structure Determination	<i>17</i>
1.3.3	Inelastic Scattering	<i>17</i>
1.4	Further Reading	<i>17</i>
1.5	Discussion and Problems	<i>18</i>
	Discussion	<i>18</i>
	Basic Concepts	<i>18</i>
	Problems	<i>20</i>
2	Bonding in Solids	<i>23</i>
2.1	Attractive and Repulsive Forces	<i>23</i>
2.2	Ionic Bonding	<i>24</i>
2.3	Covalent Bonding	<i>25</i>

2.4	Metallic Bonding	32
2.5	Hydrogen Bonding	33
2.6	Van der Waals Bonding	33
2.7	Further Reading	34
2.8	Discussion and Problems	34
	Discussion	34
	Basic Concepts	35
	Problems	35
3	Mechanical Properties	37
3.1	Elastic Deformation	39
3.1.1	Macroscopic Picture	39
3.1.1.1	Elastic Constants	39
3.1.1.2	Poisson's Ratio	40
3.1.1.3	Relation Between Elastic Constants	40
3.1.2	Microscopic Picture	41
3.2	Plastic Deformation	43
3.2.1	Estimate of the Yield Stress	43
3.2.2	Point Defects and Dislocations	45
3.2.3	The Role of Defects in Plastic Deformation	45
3.3	Fracture	47
3.4	Further Reading	48
3.5	Discussion and Problems	48
	Discussion	48
	Basic Concepts	49
	Problems	49
4	Thermal Properties of the Lattice	51
4.1	Lattice Vibrations	51
4.1.1	A Simple Harmonic Oscillator	51
4.1.2	An Infinite Chain of Atoms	52
4.1.2.1	One Atom Per Unit Cell	52
4.1.2.2	The First Brillouin Zone	55
4.1.2.3	Two Atoms per Unit Cell	56
4.1.3	A Finite Chain of Atoms	58
4.1.4	Quantized Vibrations, Phonons	59
4.1.5	Three-Dimensional Solids	61
4.1.5.1	Generalization to Three Dimensions	61
4.1.5.2	Estimate of the Vibrational Frequencies from the Elastic Constants	63
4.2	Heat Capacity of the Lattice	64
4.2.1	Classical Theory and Experimental Results	65
4.2.2	Einstein Model	66
4.2.3	Debye Model	68
4.3	Thermal Conductivity	71
4.4	Thermal Expansion	74

4.5	Allotropic Phase Transitions and Melting	75
	References	78
4.6	Further Reading	78
4.7	Discussion and Problems	78
	Discussion	78
	Basic Concepts	79
	Problems	81
5	Electronic Properties of Metals: Classical Approach	85
5.1	Basic Assumptions of the Drude Model	85
5.2	Results from the Drude Model	87
5.2.1	DC Electrical Conductivity	87
5.2.2	Hall Effect	89
5.2.3	Optical Reflectivity of Metals	90
5.2.4	The Wiedemann–Franz Law	93
5.3	Shortcomings of the Drude Model	93
5.4	Further Reading	94
5.5	Discussion and Problems	95
	Discussion	95
	Basic Concepts	95
	Problems	96
6	Electronic Properties of Solids: Quantum Mechanical Approach	99
6.1	The Idea of Energy Bands	100
6.2	The Free Electron Model	103
6.2.1	The Quantum-Mechanical Eigenstates	103
6.2.2	Electronic Heat Capacity	107
6.2.3	The Wiedemann–Franz Law	108
6.2.4	Screening	108
6.3	The General Form of the Electronic States	111
6.4	Nearly-Free Electron Model: Band Formation	114
6.5	Tight-binding Model	119
6.6	Energy Bands in Real Solids	124
6.7	Transport Properties	130
6.8	Brief Review of Some Key Ideas	134
	References	135
6.9	Further Reading	135
6.10	Discussion and Problems	136
	Discussion	136
	Basic Concepts	137
	Problems	140
7	Semiconductors	145
7.1	Intrinsic Semiconductors	146
7.1.1	Temperature Dependence of the Carrier Density	148

7.2	Doped Semiconductors	153
7.2.1	n and p Doping	153
7.2.2	Carrier Density	155
7.3	Conductivity of Semiconductors	157
7.4	Semiconductor Devices	158
7.4.1	The pn Junction	158
7.4.2	Transistors	163
7.4.3	Optoelectronic Devices	165
7.5	Further Reading	168
7.6	Discussion and Problems	169
	Discussion	169
	Basic Concepts	170
	Problems	172
8	Magnetism	175
8.1	Macroscopic Description	175
8.2	Quantum-Mechanical Description of Magnetism	177
8.3	Paramagnetism and Diamagnetism in Atoms	179
8.4	Weak Magnetism in Solids	182
8.4.1	Diamagnetic Contributions	183
8.4.1.1	Contribution from the Atoms	183
8.4.1.2	Contribution from the Free Electrons	183
8.4.2	Paramagnetic Contributions	183
8.4.2.1	Curie Paramagnetism	184
8.4.2.2	Pauli Paramagnetism	185
8.5	Magnetic Ordering	187
8.5.1	Magnetic Ordering and the Exchange Interaction	187
8.5.2	Magnetic Ordering for Localized Spins	189
8.5.3	Magnetic Ordering in a Band Picture	193
8.5.4	Ferromagnetic Domains	195
8.5.5	Hysteresis	196
	Reference	198
8.6	Further Reading	198
8.7	Discussion and Problems	199
	Discussion	199
	Basic Concepts	200
	Problems	201
9	Dielectrics	203
9.1	Macroscopic Description	203
9.2	Microscopic Polarization	205
9.3	The Local Field	207
9.4	Frequency Dependence of the Dielectric Constant	208
9.4.1	Excitation of Lattice Vibrations	208
9.4.2	Electronic Transitions	212

9.5	Other Effects	213
9.5.1	Impurities in Dielectrics	213
9.5.2	Ferroelectricity	214
9.5.3	Piezoelectricity	215
9.5.4	Dielectric Breakdown	216
9.6	Further Reading	216
9.7	Discussion and Problems	216
	Discussion	216
	Basic Concepts	217
	Problems	218
10	Superconductivity	221
10.1	Basic Experimental Facts	222
10.1.1	Zero Resistivity	222
10.1.2	The Meissner Effect	225
10.1.3	The Isotope Effect	227
10.2	Some Theoretical Aspects	227
10.2.1	Phenomenological Theory	227
10.2.2	Microscopic BCS Theory	230
10.3	Experimental Detection of the Gap	236
10.4	Coherence of the Superconducting State	238
10.5	Type-I and Type-II Superconductors	239
10.6	High-Temperature Superconductivity	242
10.7	Concluding Remarks	243
	References	244
10.8	Further Reading	244
10.9	Discussion and Problems	244
	Discussion	244
	Basic Concepts	245
	Problems	246
11	Finite Solids and Nanostructures	249
11.1	Quantum Confinement	250
11.2	Surfaces and Interfaces	252
11.3	Magnetism on the Nanoscale	255
11.4	Further Reading	256
11.5	Discussion and Problems	257
	Discussion	257
	Basic Concepts	257
	Problems	257
Appendix A		259
A.1	Explicit Forms of Vector Operations	259
A.2	Differential Form of the Maxwell Equations	260
A.3	Maxwell Equations in Matter	261

Appendix B 263

B.1 Solutions to Basic Concepts Questions 263

Index 265