

Contents

Preface to the Fourth Edition	v
Preface to the Third Edition	vii
Preface to the Second Edition	ix
Preface to the First Edition	xi

PART I Fundamentals of Electron Theory

CHAPTER 1	
Introduction	3

CHAPTER 2	
The Wave-Particle Duality	7
Problems	14

CHAPTER 3	
The Schrödinger Equation	15
3.1. The Time-Independent Schrödinger Equation	15
*3.2. The Time-Dependent Schrödinger Equation	16
*3.3. Special Properties of Vibrational Problems	17
Problems	18

CHAPTER 4	
Solution of the Schrödinger Equation for Four Specific Problems	19
4.1. Free Electrons	19
4.2. Electron in a Potential Well (Bound Electron)	21

4.3. Finite Potential Barrier (Tunnel Effect)	25
4.4. Electron in a Periodic Field of a Crystal (The Solid State)	29
Problems	36

CHAPTER 5

Energy Bands in Crystals	37
5.1. One-Dimensional Zone Schemes	37
5.2. One- and Two-Dimensional Brillouin Zones	42
*5.3. Three-Dimensional Brillouin Zones	45
*5.4. Wigner–Seitz Cells	46
*5.5. Translation Vectors and the Reciprocal Lattice	48
*5.6. Free Electron Bands	52
5.7. Band Structures for Some Metals and Semiconductors	56
5.8. Curves and Planes of Equal Energy	59
Problems	61

CHAPTER 6

Electrons in a Crystal	63
6.1. Fermi Energy and Fermi Surface	63
6.2. Fermi Distribution Function	64
6.3. Density of States	65
6.4. Complete Density of States Function Within a Band	67
6.5. Population Density	68
6.6. Consequences of the Band Model	70
6.7. Effective Mass	71
6.8. Conclusion	74
Problems	74
Suggestions for Further Reading (Part I)	75

PART II

Electrical Properties of Materials

CHAPTER 7

Electrical Conduction in Metals and Alloys	79
7.1. Introduction	79
7.2. Survey	80
7.3. Conductivity—Classical Electron Theory	82
7.4. Conductivity—Quantum Mechanical Considerations	85
7.5. Experimental Results and Their Interpretation	89
7.5.1. Pure Metals	89
7.5.2. Alloys	90
7.5.3. Ordering	92
7.6. Superconductivity	93
7.6.1. Experimental Results	95
*7.6.2. Theory	100

7.7. Thermoelectric Phenomena	103
7.8. Galvanoelectric Phenomena (<i>Batteries</i>)	105
7.8.1. Primary Cells	105
7.8.2. Secondary Cells	108
7.8.3. Closing Remarks	112
Problems	113

CHAPTER 8

Semiconductors	115
8.1. Band Structure	115
8.2. Intrinsic Semiconductors	117
8.3. Extrinsic Semiconductors	122
8.3.1. Donors and Acceptors	122
8.3.2. Band Structure	123
8.3.3. Temperature Dependence of the Number of Carriers	124
8.3.4. Conductivity	125
8.3.5. Fermi Energy	126
*8.4. Effective Mass	127
8.5. Hall Effect	127
8.6. Compound Semiconductors	129
8.7. Semiconductor Devices	131
8.7.1. Metal–Semiconductor Contacts	131
8.7.2. Rectifying Contacts (Schottky Barrier Contacts)	132
8.7.3. Ohmic Contacts (Metallizations)	136
8.7.4. p – n Rectifier (Diode)	137
8.7.5. Zener Diode	140
8.7.6. Solar Cell (Photodiode)	141
*8.7.7. Avalanche Photodiode	145
*8.7.8. Tunnel Diode	145
8.7.9. Transistors	147
*8.7.10. Quantum Semiconductor Devices	156
8.7.11. Semiconductor Device Fabrication	159
*8.7.12. Digital Circuits and Memory Devices	168
Problems	177

CHAPTER 9

Electrical Properties of Polymers, Ceramics, Dielectrics, and Amorphous Materials	181
9.1. Conducting Polymers and Organic Metals	181
9.2. Ionic Conduction	191
9.3. Conduction in Metal Oxides	194
9.4. Amorphous Materials (Metallic Glasses)	196
9.4.1. Xerography	200
9.5. Dielectric Properties	202
9.6. Ferroelectricity, Piezoelectricity, Electrostriction, and Pyroelectricity	206
Problems	210
Suggestions for Further Reading (Part II)	210

PART III

Optical Properties of Materials

CHAPTER 10

The Optical Constants	215
10.1. Introduction	215
10.2. Index of Refraction, n	217
10.3. Damping Constant, k	218
10.4. Characteristic Penetration Depth, W , and Absorbance, α	222
10.5. Reflectivity, R , and Transmittance, T	223
10.6. Hagen–Rubens Relation	225
Problems	225

CHAPTER 11

Atomistic Theory of the Optical Properties	227
11.1. Survey	227
11.2. Free Electrons Without Damping	230
11.3. Free Electrons With Damping (Classical Free Electron Theory of Metals)	233
11.4. Special Cases	236
11.5. Reflectivity	237
11.6. Bound Electrons (Classical Electron Theory of Dielectric Materials)	238
*11.7. Discussion of the Lorentz Equations for Special Cases	242
11.7.1. High Frequencies	242
11.7.2. Small Damping	242
11.7.3. Absorption Near ν_0	243
11.7.4. More Than One Oscillator	243
11.8. Contributions of Free Electrons and Harmonic Oscillators to the Optical Constants	244
Problems	245

CHAPTER 12

Quantum Mechanical Treatment of the Optical Properties	247
12.1. Introduction	247
12.2. Absorption of Light by Interband and Intraband Transitions	247
12.3. Optical Spectra of Materials	251
*12.4. Dispersion	251
Problems	256

CHAPTER 13

Applications	259
13.1. Measurement of the Optical Properties	259
*13.1.1. Kramers–Kronig Analysis (Dispersion Relations)	260
*13.1.2. Spectroscopic Ellipsometry	260
*13.1.3. Differential Reflectometry	263
13.2. Optical Spectra of Pure Metals	266
13.2.1. Reflection Spectra	266
*13.2.2. Plasma Oscillations	270

13.3. Optical Spectra of Alloys	271
*13.4. Ordering	275
*13.5. Corrosion	277
13.6. Semiconductors	278
13.7. Insulators (Dielectric Materials and Glass Fibers)	281
13.8. Emission of Light	284
13.8.1. Spontaneous Emission	284
13.8.2. Stimulated Emission (Lasers)	288
13.8.3. Helium–Neon Laser	291
13.8.4. Carbon Dioxide Laser	292
13.8.5. Semiconductor Laser	293
13.8.6. Direct–Versus Indirect–Band Gap Semiconductor Lasers	295
13.8.7. Wavelength of Emitted Light	296
13.8.8. Threshold Current Density	297
13.8.9. Homojunction Versus Heterojunction Lasers	298
13.8.10. Laser Modulation	299
13.8.11. Laser Amplifier	300
13.8.12. Quantum Well Lasers	301
13.8.13. Light-Emitting Diodes (LED)	302
13.8.14. Organic Light Emitting Diodes (OLEDs)	305
13.8.15. Organic Photovoltaic Cells (OPVCs)	308
13.8.16. Liquid Crystal Displays (LCDs)	310
13.8.17. Emissive Flat-Panel Displays	312
13.9. Integrated Optoelectronics	315
13.9.1. Passive Waveguides	315
13.9.2. Electro-Optical Waveguides (EOW)	317
13.9.3. Optical Modulators and Switches	319
13.9.4. Coupling and Device Integration	320
13.9.5. Energy Losses	322
13.9.6. Photonics	323
13.9.7. Optical Fibers	324
13.10. Optical Storage Devices	325
13.11. The Optical Computer	329
13.12. X-Ray Emission	332
Problems	334
Suggestions for Further Reading (Part III)	335

PART IV

Magnetic Properties of Materials

CHAPTER 14

Foundations of Magnetism	339
14.1. Introduction	339
14.2. Basic Concepts in Magnetism	340
*14.3. Units	344
Problems	345

CHAPTER 15

Magnetic Phenomena and Their Interpretation—Classical Approach	347
15.1. Overview	347
15.1.1. Diamagnetism	347
15.1.2. Paramagnetism	349
15.1.3. Ferromagnetism	352
15.1.4. Antiferromagnetism	358
15.1.5. Ferrimagnetism	359
15.2. Langevin Theory of Diamagnetism	362
*15.3. Langevin Theory of (Electron Orbit) Paramagnetism	364
*15.4. Molecular Field Theory	368
Problems	371

CHAPTER 16

Quantum Mechanical Considerations	373
16.1. Paramagnetism and Diamagnetism	373
16.2. Ferromagnetism and Antiferromagnetism	378
Problems	382

CHAPTER 17

Applications	385
17.1. Introduction	385
17.2. Electrical Steels (Soft Magnetic Materials)	385
17.2.1. Core Losses	386
17.2.2. Grain Orientation	388
17.2.3. Composition of Core Materials	390
17.2.4. Amorphous Ferromagnets	390
17.3. Permanent Magnets (Hard Magnetic Materials)	391
17.4. Magnetic Recording and Magnetic Memories	394
17.4.1. Closing Remarks	400
Problems	400
Suggestions for Further Reading (Part IV)	400

PART V**Thermal Properties of Materials****CHAPTER 18**

Introduction	405
---------------------	-----

CHAPTER 19

Fundamentals of Thermal Properties	409
19.1. Heat, Work, and Energy	409
19.2. Heat Capacity, C'	410
19.3. Specific Heat Capacity, c	411
19.4. Molar Heat Capacity, C_v	412

Contents	xix
19.5. Thermal Conductivity, K	413
19.6. The Ideal Gas Equation	414
19.7. Kinetic Energy of Gases	415
Problems	416
 CHAPTER 20	
Heat Capacity	419
20.1. Classical (Atomistic) Theory of Heat Capacity	419
20.2. Quantum Mechanical Considerations—The Phonon	421
20.2.1. Einstein Model	421
20.2.2. Debye Model	424
20.3. Electronic Contribution to the Heat Capacity	426
Problems	429
 CHAPTER 21	
Thermal Conduction	431
21.1. Thermal Conduction in Metals and Alloys—Classical Approach	432
21.2. Thermal Conduction in Metals and Alloys—Quantum Mechanical Considerations	434
21.3. Thermal Conduction in Dielectric Materials	435
Problems	437
 CHAPTER 22	
Thermal Expansion	439
Problems	441
Suggestions for Further Reading (Part V)	441
 Appendices	443
App. 1. Periodic Disturbances	445
App. 2. Euler Equations	450
App. 3. Summary of Quantum Number Characteristics	451
App. 4. Tables	454
App. 5. About Solving Problems and Solutions to Problems	467
 About the Author	473
 Index	475

Note: Sections marked with an asterisk (*) are topics which are beyond a 15-week semester course or may be treated in a graduate course.



<http://www.springer.com/978-1-4419-8163-9>

Electronic Properties of Materials

Hummel, R.E.

2011, XIX, 488 p., Hardcover

ISBN: 978-1-4419-8163-9