

CONTENTS

PREFACE	xiii
FOREWORD TO THE STUDENT	xvii
1 INTRODUCTION	3
1.1 What is Materials Science?	3
1.2 What is Structure?	22
1.3 What are Properties?	32
1.4 How is Materials Science Relevant?	45
REFERENCES	53
PROBLEMS	54
2 MECHANICAL PROPERTIES	59
2.1 Plastic Deformation of Solids	59
2.2 Special Deformation Behavior of Solids	65
2.3 The Flow of Fluids	74
2.4 Internal Friction in Solids	77
2.5 Ideal Plastic Behavior	85
REFERENCES	86
PROBLEMS	87
3 ELECTRIC AND MAGNETIC PROPERTIES	95
3.1 Introduction	95
3.2 Ohm's Law and the Hall Coefficient	99
3.3 Metals and Semiconductors	104
3.4 Insulators	109
3.5 Special Dielectrics	117

3.6	Magnetic Properties	122
3.7	Soft Ferromagnetics	130
3.8	Hard Magnetic Materials	134
3.9	Special Magnetic Materials	136
3.10	Superconductors	137
	REFERENCES	142
	PROBLEMS	144

4 THERMAL AND CHEMICAL PROPERTIES **151**

4.1	Space Rockets and Thermal Expansion Coefficient	151
4.2	Thermal Conductivity	153
4.3	Heat Capacity	159
4.4	Energy Changes During Phase Transformation	161
4.5	Temperature Effects on Properties	162
4.6	Electrical-Thermal Coupling	165
4.7	Heat Treatment	168
4.8	Chemical Properties	169
4.9	Summary of Properties	172
	REFERENCES	174
	PROBLEMS	175

5 BINDING IN ATOMS, MOLECULES AND CRYSTALS **179**

5.1	Wave Mechanics	179
5.2	The Schrödinger Equation	187
5.3	The Hydrogen Atom	193
5.4	The Hydrogenlike Atom and the Periodic Table	196
5.5	Bonding of Atoms in Molecules and Condensed Phases	202
5.6	Covalent Bonding	208
5.7	Binding in Metals	213
5.8	Secondary Bonds	214
5.9	Polarization and Magnetization	220
	REFERENCES	225
	PROBLEMS	225

6 ATOMIC ARRANGEMENTS **233**

6.1	Crystals and Lattices	233
6.2	Some Simple Crystals	238
6.3	Crystallographic Directions and Planes	242
6.4	Packing of Atoms in Crystals	247

6.5 Symmetry and its Relationship to Properties 261
 6.6 Imperfections in Crystals 267
 6.7 Glasses 283
 6.8 Diffraction by Crystals 288
 REFERENCES 293
 PROBLEMS 295

7 POLYMERS 303

7.1 Introduction 303
 7.2 An Idealized Random Chain 306
 7.3 Degree of Polymerization 307
 7.4 The Topology of Vinyl Polymers 310
 7.5 Other Addition Polymers 314
 7.6 Copolymers 318
 7.7 Condensation Polymers 319
 7.8 Network Polymers 324
 7.9 Thermoplastics and Thermosetting Resins 326
 7.10 Crystallinity in Polymers 326
 7.11 Macromolecules in Living Matter 328
 REFERENCES 332
 PROBLEMS 333

8 MICRO- AND MACRO-STRUCTURE 337

8.1 Single Crystals 337
 8.2 The Reflection Microscope 339
 8.3 Polycrystalline Materials 347
 8.4 Polyphase Materials 353
 8.5 Composite Materials 355
 8.6 Quantitative Microscopy 363
 REFERENCES 365
 PROBLEMS 366

9 EQUILIBRIUM AND KINETICS 369

9.1 Atom Motion and Temperature 369
 9.2 Kinetics in an Ideal Gas 376
 9.3 Internal Energy 380
 9.4 Randomness and Entropy 382
 9.5 Equilibrium in Chemical Systems 386
 9.6 The Barometric Formula 389

9.7	Atom Vibrations	392	
9.8	Kinetics of Reactions	396	
9.9	Introduction to Diffusion	399	
9.10	Special Cases of Diffusion	406	
9.11	Applications of Diffusion Theory	415	
9.12	Nucleation	419	
	REFERENCES	424	
	PROBLEMS	424	
10	PHASE DIAGRAMS		431
10.1	Introduction	431	
10.2	Binary Systems	435	
10.3	Nonequilibrium Transformations	447	
10.4	Age Precipitation Hardening	453	
10.5	The Fe-C System	458	
10.6	Segregation in Binary Alloys During Solidification	468	
	REFERENCES	473	
	PROBLEMS	474	
11	ELECTROCHEMICAL PROPERTIES		479
11.1	Introduction	479	
11.2	Half-Cell Potentials	485	
11.3	Polarization and Overvoltage	491	
11.4	Corrosion	496	
11.5	Protecting Against Corrosion	501	
	REFERENCES	505	
	PROBLEMS	506	
12	STRENGTHENING MECHANISMS		511
12.1	How Strong Can Materials Be?	511	
12.2	Why are Bulk Materials so Weak?	518	
12.3	General Strengthening Concepts	527	
12.4	Solute Strengthening	529	
12.5	Strain Hardening	530	
12.6	Strengthening by Grain Boundaries	538	
12.7	Second Phase Strengthening	540	
12.8	Strengthening by Martensitic Transformation	547	
12.9	Strengthening at High Temperatures	553	
12.10	Strengthening Mechanisms in Polymers	559	

12.11	Strengthening of Viscous Matrices	560
	REFERENCES	561
	PROBLEMS	562
13	ELECTRONS IN CONDENSED PHASES	567
13.1	The Electron Gas	567
13.2	The Quantized Electron Gas	571
13.3	Electrons in a Periodic Potential	579
13.4	Brillouin Zones	582
13.5	Conductivity	585
13.6	Intrinsic Semiconductors	593
13.7	Extrinsic Semiconductors	596
13.8	The p-n Junction	602
13.9	The Junction Transistor	608
13.10	Lasers	611
	REFERENCES	615
	PROBLEMS	615
14	MAGNETISM	621
14.1	Diamagnetism	621
14.2	Paramagnetism	624
14.3	Ferromagnetism	632
14.4	Antiferromagnetism and Ferrimagnetism	636
14.5	Domains	639
14.6	Magnetization Processes According to Domain Theory	645
14.7	Magnetic Bubbles	650
	REFERENCES	653
	PROBLEMS	654
15	SUPERCONDUCTIVITY	657
15.1	The Superconducting State	657
15.2	Fundamental Concepts	659
15.3	Collective de Broglie Wave	663
15.4	The Penetration Depth	665
15.5	Magnetic Flux Quantization	666
15.6	Type I vs Type II Superconductors	667
15.7	Fluxoid Pinning	672
	REFERENCES	674
	PROBLEMS	675
	EPILOGUE	677
	INDEX	679