Contents

I HIGHLIGHTS, OPPORTUNITIES, AND NEEDS

Condensed-Matter Physics and Its Importance, 3 Discovery, 6

Artificially Structured Materials, 6

The Quantized Hall Effect, 7

Effects of Reduced Dimensionality, 8

Charge-Density Waves, 8

Disorder, 9

Mixed Valence and Heavy Fermions, 10

The Superfluid Phases of ³He, 10

The Renormalization Group Methods, 11

Chaotic Phenomena in Time and Space, 12

Widespread Use of Synchrotron Radiation, 12

Atomic Resolution Experimental Probes, 13

Research Opportunities in Condensed-Matter Physics in the Next Decade, 14

Needs of Condensed-Matter Physics in the Next Decade, 19

Support for Individual Researchers, 21 Manpower, 21; Instrumentation, 23; Computation, 25; Funding, 26

Support for National Facilities, 27 Neutron Facilities, 28; Synchrotron Radiation Sources

• •	
XII	CONTENTS

	Recommendations, 31; General Recommendations Concerning National Facilities, 32 University-Industry-Government Relations, 33	
I	A DECADE OF CONDENSED-MATTER PHYSICS	
1	ELECTRONIC STRUCTURE AND PROPERTIES OF MATTER Introduction, 39 Advances in Electronic Structure Determinations, 40 Many-Electron Effects, 41 Quantized Hall Effect, 42 Electron-Hole Droplets, 45 Electronically Ordered States, 45 Disordered Systems, 47	39
	Mixed Media, 53 Condensed Matter at High Pressure, 53 Opportunities, 55	
2	STRUCTURES AND VIBRATIONAL PROPERTIES OF SOLIDS Introduction, 58 Theoretical Calculations, 59 Measurements of Structures and Phonon Spectra, 61 Phonon Transport, 64 Electron-Phonon Interactions, 65 Disordered Solids and Incommensurate Phases, 69	58
	Phase Transitions and Nonlinear Excitations, 71 Opportunities, 72	
3	CRITICAL PHENOMENA AND PHASE TRANSITIONS	75

Recommendations, 29; High-Magnetic-Field Facilities

Recommendations, 31; Electron-Microscope Facilities

	What Does One Measure? 80	
	What Determines the Universality Class? 84	
	Experimental Realizations of Low-Dimensional	
	Systems, 87	
	Multicritical Points, 88	
	Systems with Almost-Broken Symmetry, 88	
	Two-Dimensional Superfluid and XY Model, 89	
	Melting of a Two-Dimensional Crystal, 89	
	Smectic A-to-Nematic Transition, 90	
	Quenched Disorder, 91	
	Percolation and the Metal-Insulator Transition in	
	Disordered Systems, 92	
	Nonequilibrium Systems, 92	
	First-Order Transitions, 92	
	Outlook, 93	
4	MAGNETISM	95
	Introduction, 95	
	Magnetic Insulators, 97	
	Low-Dimensional Systems, 97	
	Critical Phenomena, 100	
	Metallic Magnets, 100	
	Transition-Metal Ferromagnets, 100	
	Rare-Earth and Actinide Magnets, 103	
	Disordered Systems, 105	
	Introduction, 105	
	Disordered Ferromagnets, Antiferromagnets, and	
	Paramagnets, 106	
	Spin Glasses, 108	
	Computer Simulations in Magnetism, 110	
	Future Developments, 112	
_	OPACIONINI CORODO	110
5	SEMICONDUCTORS	113
	Introduction, 113	
	Surfaces and Interfaces, 115	
	Defects in Semiconductors, 117	
	Reduced Dimensionality in Semiconductors, 118	
	Optical Properties of Compound Semiconductors, 119	

Amorphous Semiconductors, 121

	Future Prospects, 122	
	Semiconductor Surfaces and Interfaces, 122	
	Semiconductor-Semiconductor Interfaces, 123;	
	Semiconductor-Insulator Interfaces, 123; Semiconductor-	
	Metal Interfaces, 124	
	Defects in Semiconductors, 124	
	Systems of Reduced Dimensionality, 125	
	Quantized Hall Effect, 125; Growth Techniques and	
	Lithography, 125; Small Structures, 125;	
	Heterostructures, 126; The Two-Dimensional Wigner	
	Crystal, 126	
6	DEFECTS AND DIFFUSION	127
6	Introduction, 127	12,
	New Fields from Old: An Example, 128	
	Phase Microstructure and Phase Generation in	
	Radiation Fields, 129	
	Surface and Near-Surface Probes, 130	
	Ion-Beam Microfabrication, 131	
	Calculations of Defect Structure, 132	
	Fundamentals of Atomic Mobility, 134	
	Comments on Active Areas, 137	
	Point Defects in Simple Solids, 137	
	Surface Diffusion, 138	
	Photochemical Processes, 139	
	Molecular Dynamics, 139	
	Dislocation Motion in Glasses, 140	
	Defect Imaging at Atomic Resolution, 141	
	Some Directions for Future Research, 142	
5340		1 1 1
7	SURFACES AND INTERFACES	144
	Introduction, 144	
	The Structure of the Crystal Surface, 147	
	Spectroscopy and Elementary Excitations on	
	the Surface, 151	
	Interactions of Atoms and Molecules on	
	the Surface, 155	

	The Interface Between Solids and Dense	
	Media, 157	
	Theory, 159 Opportunities, 160	
	Opportunities, 160	
8	LOW-TEMPERATURE PHYSICS	164
	Definition of Subfield, 164	
	Quantum Fluids, 164	
	Superfluid ³ He, 166	
	Nuclear Magnetic Resonance in Superfluid ³ He, 170;	
	Ultrasound, 170; Other Sound Modes, 171; Defects, 171;	
	Superfluid Flow and Hydrodynamics, 172	
	Novel Quantum Fluids, 172	
	Mixtures of ³ He in ⁴ He, 173; Spin-Polarized Hydrogen and Deuterium, 173; Liquid ⁴ He in Unusual Geometries,	
	174; Electrons on Helium Surfaces, 175	
	Superconductivity, 176	
	Nonequilibrium Superconductivity, 179	
	Novel Superconducting Materials, 179	
	Magnetic Superconductors, 180	
	High-Transition-Temperature, High-Magnetic-	
	Field Materials, 180	
	The Josephson Effects, 182	
	Quantum Crystals, 182	
	Low-Temperature Technology, 185	
	Research Opportunities in Low-Temperature	
	Physics, 187	
9	LIQUID-STATE PHYSICS	190
 3	Classical Liquids, 190	170
	Introduction, 190	
	Static Properties, 191	
	Dynamical Properties of Classical Liquids, 193	
	Colloidal Systems—Soap Solutions, 198	
	Liquid Crystals, 199	
	What Are Liquid Crystals? 199	
	Why Are Liquid Crystals Interesting? 200	
	Major Advances, 202	
	Opportunities for Future Work, 203	

xvi	CONTENTS	
10	POLYMERS Introduction, 206 Research Problems, 207 Amorphous State—Solutions and Melts, 207 Glass, 209 Elastomers, Gels, Cross-linked Networks, 209 Polymer Crystals, 210 Electrical Properties, 211 Other Polymer Properties, 212 Opportunities, 213	206
	NONLINEAR DYNAMICS, INSTABILITIES, AND CHAOS Introduction, 215 Major Advances, 216 A New Paradigm, 216 New Experimental Methods, 217 Routes to Chaos, 217 Dynamical Systems Theory of the Routes to Turbulence, 219 Dynamical Systems Analysis of Experiments, 221 Nonlinear Stability Theory, 222 Pattern Evolution, 223 Instabilities in Other Dissipative Systems, 223 Nonlinear Dynamics of Conservative Systems, 225 General Remarks, 226 Current Frontiers, 227 Bifurcation Sequences, 227 Patterns, 228	215
	Numerical Simulations, 228 Experimental Methods, 229 Transition from Weak to Fully Developed Turbulence, 229 Conservative Systems, 230	

Nonequilibrium Systems, 231

New Directions, 232

APPENDIXES

A	Connections Between Subareas of Condensed-Matter Physics and Applications of National Interest	236
В	New Experimental Techniques	246
C	New Materials	248
D	Laser Spectroscopy of Condensed Matter	258
E	National Facilities	265
	CONTRIBUTORS TO THIS VOLUME	291
	INDEX	295