

Contents

EXECUTIVE SUMMARY	1
1 SUMMARY AND RECOMMENDATIONS	3
Perspectives for Society: Applications, Implications, and Interfaces of Physics, 3	
Scientific Synergy: The Scientific Interfaces of Physics, 4	
Biological Physics, 5	
Physics and Materials Science, 6	
The Physics-Chemistry Interface, 7	
Geophysics, 8	
Mathematical Physics and Computational Physics, 10	
Today's Science/Tomorrow's Technology: the Process of Innovation, 11	
Progress in the Applications of Physics: Microelectronics, 13	
Optical Technology, 15	
Instrumentation, 16	
Energy and Environment, 18	

	National Security, 20	
	Medical Applications, 21	
	Recommendations, 22	
2	BIOLOGICAL PHYSICS	26
	Introduction, 26	
	Biological Macromolecules, 29	
	Experimental Methods of Molecular Biophysics, 32	
	Biophysics of Membranes and Cell Physiology, 38	
	Biophysics of Brain and Nerve, 42	
	Membrane Channels, 43	
	Organization of Brain and Memory, 46	
	Theoretical Biophysics, 47	
	Conclusions and Recommendations, 49	
3	NEW ASPECTS OF THE PHYSICS-CHEMISTRY INTERFACE	53
	Introduction, 53	
	Instrumentation-Driven Collaboration, 55	
	Laser Science, 55	
	Surface and Interface Probes, 56	
	Neutrons and Synchrotron Radiation, 59	
	Polymers and Complex Fluids, 61	
	Organic Electronic Materials, 63	
	Conducting Molecular Crystals, 63	
	Conjugated Polymers, 64	
	Molecular Assemblies, 65	
	Recommendations, 66	
	Education, 66	
	Academic Research, 67	
	Funding, 67	
	Summary, 68	
4	PHYSICS AND MATERIALS SCIENCE	69
	Introduction, 69	
	Historical Highlights, 71	
	The Physics/Materials-Science Interface, 74	
	New Materials, 75	

	New Processes, 77	
	Chemical Separation and Analysis, 78	
	Surfaces, 78	
	Defects, 79	
	Instrumentation, 80	
	Theory and Modeling, 80	
	Amorphous and Disordered Materials, 81	
	Metallurgical Microstructures, 85	
	Concluding Remarks, 90	
5	GEOPHYSICS	91
	Introduction, 91	
	Scientific Background, 93	
	Plate Tectonics, 93	
	The Earth as a Thermodynamic Engine, 93	
	Continental Deformation, 94	
	Geochemical Reservoirs, 95	
	The Atmosphere and Oceans, 97	
	Comparative Planetology, 99	
	The Moon, 99; Mars, 99; Venus, 100	
	Applications, 101	
	Hazards, 101	
	Seismicity, 101; Volcanic Eruptions, 101	
	Energy, 102	
	Fossil Fuels, 102; Nuclear Energy, 103;	
	Geothermal Energy, 103	
	Data Acquisition from Space, 104	
	National Security, 104	
	Future Directions of Research, 105	
	Seismic Studies of the Continents, 105	
	Deep Drilling in the Continents, 105	
	Global Digital Seismic Array, 105	
	Large-Scale Computing Facilities, 106	
	Studies of Crustal and Mantle Materials Under	
	High Pressure, 106	
	Remote Sensing from Space, 106	
	Other Geophysical Data Sets, 107	
6	COMPUTATIONAL PHYSICS	108
	Introduction, 108	

	Theoretical Investigation of Complex Systems, 109	
	Elementary-Particle Physics, 110	
	Statistical Mechanics, 112	
	Condensed-Matter Theory, 112	
	Atomic and Molecular Physics, 113	
	Plasma Physics, 115	
	Nuclear Physics, 116	
	Physics of Fluids, 118	
	Astrophysics, 119	
	Gravitation Theory, 120	
	The Character of Computational Physics as Scientific Research, 120	
	Policy Implications and Recommendations, 123	
7	THE INTERFACE BETWEEN PHYSICS AND MATHEMATICS	125
	Introduction, 125	
	Field Theory and Mathematics, 126	
	Chaos at the Interface of Mathematics and Physics, 129	
8	MICROELECTRONICS AND PHYSICS	134
	Introduction, 134	
	From Transistor to Ultralarge-Scale Integration, 135	
	Decade of Very-Large-Scale Integration, 136	
	Symbiosis, 141	
	Other Technologies, 142	
	Gallium Arsenide, 142	
	Josephson Junctions—A Superconducting Computer? 145	
	Amorphous Semiconductors, 147	
	Scaling Down—Limits to Miniaturization, 147	
	Materials, 148	
	Interfaces and Surfaces, 150	
	Transport, 151	
	Packaging, 152	
	Magnetic Information Technology—Storing the Bits, 153	

	Magnetic Recording, 155	
	Magnetic Bubble Technology, 156	
	Magnetic-Optic Recording, 157	
	Into the Future, 158	
	What Next? 159	
9	APPLICATIONS OF PHYSICS TO OPTICAL INFORMATION TECHNOLOGIES	161
	Introduction, 161	
	Optical Communications Technology, 163	
	Optical Communications System Components, 163	
	Evolving Systems Configurations, 171	
	Technological Challenges, 171	
	Fiber-Optic Sensor Technology, 172	
	Optical Information Processing, 173	
	Optical Memory, 173	
	Integrated Optics and Optoelectronics, 176	
	The Photonic Future: Today's Research for Tomorrow's Technology, 176	
	All-Optical Logic, 176	
	Slicing the Second: Fundamental Limits to High Speed, 181	
	Exotic Propagation Modes and Media, 182	
	Synergy Between Optical Science and Fundamental Physics, 183	
10	INSTRUMENTATION	185
11	APPLICATIONS OF PHYSICS TO ENERGY AND ENVIRONMENTAL PRESERVATION . .	197
	Energy, 197	
	Condensed-Matter Physics and Solar-Energy Conversion, 198	
	Materials, 201	
	Fusion Energy, 202	
	Plasma-Surface Interactions, 202; Radiation Effects in Fusion Reactors, 203; Coherent Radiation Sources and Particle Acceleration Physics, 204; Inertial-Confinement Fusion, 204	

	The Role of Physics in Combustion Research, 205	
	Diagnostics for Combustion, 206; Fuel Preparation and Mixing, 206; Ignition, 206; Flame Propagation and Extinction, 206; Pollutant Formation, 206	
	Future Developments, 207	
	Environment, 208	
	Atmospheric Science, 208	
	Acid Rain, 208	
	Carbon Dioxide Concentration and the Greenhouse Effect, 210	
	Hydrospheric Studies, 212	
	Soil Physics, 213	
	Biota and Ecology, 213	
	Recommendations, 214	
12	PHYSICS AND NATIONAL SECURITY	216
	Introduction, 216	
	Examples of Recent Contributions of Physics to National Security, 217	
	Lasers and Their Applications, 218	
	Cyclotron Resonance Masers and Free-Electron Lasers, 219	
	Optical Fibers and Integrated Optics, 220	
	Accurate Clocks and Relativity Applications, 221	
	Applications of Ion Implantation, 221	
	Compound-Semiconductor Electronics, 223	
	Magnetic Bubble Memories, 223	
	Future Directions, 224	
	Sensing, Processing, and Deception, 224	
	Directed-Energy Weapons, 226	
	Low-Observables Technology, 227	
	Physics and Arms Control, 227	
	Enhancing the National-Security/Physics Interface, 229	
13	MEDICAL APPLICATIONS OF PHYSICS	236
	Introduction, 236	

Radiology, 237
 Diagnostic Radiography, 238
 Isotopes and Nuclear Medicine, 239
 X-Ray Computed Tomography, 240
 Positron Emission Tomography, 242
Ultrasonics, 243
Nuclear Magnetic Resonance, 245
Photonics and Medicine, 249
 Lasers, 249
 Fiber Optics in Endoscopes and Sensors, 251
 Fluorescence Immunoassay, 253
Closing Remarks, 254
Recommendations, 255

INDEX

257