

CONTENTS

	PAGE
Preface	iv
First stages in the x-ray analysis of proteins. By SIR LAWRENCE BRAGG	1
Photoconductivity. By T. S. MOSS	15
Neutrino physics. By M. SCHWARTZ	61
Electron beam spectroscopy. By O. KLEMPERER	77
Collective vibrations in nuclei. By A. M. GREEN	113
The equation of state of dense systems. By J. S. ROWLINSON	169
Quantum theory of many-body systems. By N. M. HUGENHOLTZ	201
Thermomagnetic effects in semiconductors and semimetals. By R. T. DELVES	249
The direct observation of imperfections in crystals. By D. W. PASHLEY	291
Some effects of point defects on the vibrations of crystal lattices. By A. A. MARADUDIN	331
X-ray microscopy. By V. E. COSSLETT	381
Astrophysical neutrinos. By M. A. RUDERMAN	411
Solid-state polymerization induced by radiation. By A. CHARLESBY	463

Photoconductivity

T. S. MOSS

Royal Aircraft Establishment, Farnborough, Hants.

Contents

	Page
1. Introduction	15
2. Theory	17
2.1. High resistivity material (photostatic effects)	18
2.2. Low resistivity material	20
2.3. Photovoltaic effects	20
2.4. Photoconductivity	21
2.5. Photoelectromagnetic effect	24
2.6. p-n junctions and solar batteries	26
2.7. Trapping effects	32
3. Experimental	34
3.1. Group IV elements	35
3.1.1. Diamond	35
3.1.2. Silicon	36
3.1.3. Germanium	38
3.1.4. Gray tin	40
3.2. Group III-V compounds	41
3.2.1. Indium antimonide	41
3.2.2. Indium arsenide	45
3.2.3. Indium phosphide	46
3.2.4. Aluminium antimonide	46
3.2.5. Aluminium arsenide	47
3.2.6. Aluminium phosphide	47
3.2.7. Gallium antimonide	47
3.2.8. Gallium arsenide	48
3.2.9. Gallium phosphide	50
3.3. Group II-VI compounds	51
3.3.1. Zinc chalcogenides	52
3.3.2. Cadmium chalcogenides	53
3.3.3. Mercury chalcogenides	56
References	57
Appendix—Symbols	59

Neutrino physics

M. SCHWARTZ

Columbia University, New York, U.S.A.

Contents

	Page
1. Introduction	61
2. Historical survey	61
3. Some additional theoretical background	64
3.1. 'Elastic' processes	65
3.2. Production of intermediate bosons	66
4. Current neutrino experiments	67
4.1. 'Elastic' interactions	70
4.2. Intermediate boson	70
4.3. Lepton conservation	71
4.4. The interaction of electron type neutrinos	71
5. Limitations of the present experiments and the outlook for future neutrino physics	71
References	75

Electron beam spectroscopy

O. KLEMPERER

Department of Physics, Imperial College, London

Contents

	Page
1. Introduction	77
2. Early developments	78
3. Guns for electron beam spectroscopy	80
4. Spectrometers with deflection analysers	86
5. Retarding field analysers	91
6. Monochromators and decelerators for increasing the resolution in electron beam spectrometers	101
References	109

Collective vibrations in nuclei

A. M. GREEN†

Institute of Theoretical Physics, Copenhagen, Denmark

Contents

	Page
1. Introduction	113
2. Theoretical survey	114
2.1. Giant dipole resonance	114
2.2. Models	116
2.3. Schematic model	118
2.4. Ground-state correlations	120
2.5. Extended schematic model	122
2.6. Approximate collective wave functions	124
2.7. Sum rules	125
3. Oxygen 16	126
3.1. 0^+ level at 6.06 mev	137
3.2. Structure of the giant dipole resonance	138
3.3. Sum rules	140
4. Calcium 40	141
5. Lead 208	146
6. Vibrations in non-double closed-shell nuclei	148
6.1. Effect of pairing	148
6.2. Deformed nuclei	154
7. Magnesium 24	157
8. Brief survey of other nuclei	160
8.1. Carbon	161
8.2. Oxygen isotopes	161
8.3. Silicon	161
8.4. Zirconium	162
9. Conclusion	162
Acknowledgments	163
References	163

The equation of state of dense systems

J. S. ROWLINSON

Department of Chemical Engineering and Chemical Technology, Imperial College of Science and Technology, London

Contents

	Page
1. Introduction	169
2. The experimental position	170
3. Statistical mechanics	173
3.1. The intermolecular potential	173
3.2. Distribution and correlation functions	174
3.3. Virial expansions	176
4. Direct calculation of the properties of model systems	178
4.1. Hard spheres	179
4.2. Square-well potential	182
4.3. Lennard-Jones potential	182
4.4. Gaussian model	182
4.5. Hard cubes	183
5. Recent theories of dense fluids	183
5.1. Definitions	183
5.2. The netted-chain approximation	185
5.3. The hyper-netted chain approximation	185
5.4. The approximation of Percus and Yevick	188
5.5. The scaled-particle model	192
5.6. Perturbations of assemblies of hard spheres	193
6. Prospects	194
References	196

Quantum theory of many-body systems

N. M. HUGENHOLTZ

Physical Laboratory of the University, Groningen, Netherlands

Contents

	Page
1. Introduction	201
2. Models	203
2.1. The Fermi gas model for nuclear matter	203
2.2. The electron gas	205
2.3. The BCS model	205
2.4. The imperfect Bose gas	206
3. Quasi-particles	208
3.1. Single-particle excitations	208
3.2. Collective excitations	211
3.3. Quasi-particles in a Bose gas	213
4. Formal methods	214
4.1. Perturbation theory	214
4.2. The resolvent method	219
4.3. Single-particle states	221
4.4. Validity of perturbation theory	223
4.5. Green's functions	224
4.6. Green's functions for finite T	229
5. The imperfect Bose gas	231
6. The BCS model	239
7. Quantum mechanics of infinite systems	243
References	245

Thermomagnetic effects in semiconductors and semimetals

R. T. DELVES

Royal Radar Establishment, Great Malvern, Worcs.

Contents

	Page
1. Definition of the effects	250
1.1. Introduction	250
1.2. The Hall and magnetoresistance effects	251
1.3. The Seebeck effect	251
1.4. The Nernst effect	252
1.5. The Peltier effect	252
1.6. The Ettingshausen effect	252
1.7. The significance of the Peltier and Ettingshausen effects	252
1.8. The thermal conductivity	253
1.9. The Righi-Leduc effect	253
1.10. Phonon drag effects	254
2. Phenomenological relations	254
2.1. The Onsager relations	254
2.2. The adiabatic and isothermal effects	255
2.3. The transverse electrical corrections	256
2.4. The Thomson effect	256
2.5. Nomenclature	257
2.6. Induction and non-local effects	257
3. The Boltzmann equation	257
3.1. Derivation of the Boltzmann equation	257
3.2. Limitations of the Boltzmann equation	260
3.3. The scattering mechanisms	262
4. The symmetry of the thermomagnetic effects	262
4.1. A relaxation time which is the same function of energy in all directions	262
4.2. Anisotropic extrinsic many-valley semiconductors	264
4.3. Symmetry compared with experiment	265
5. Spherical energy bands	265
6. Extrinsic semiconductors—comparison with experiment	267
7. Two-band conduction—ambipolar effects	270
8. Phonon drag effects	272
8.1. Introduction	272
8.2. Phonon drag in a many-valley semiconductor	274
8.3. Phonon drag effects in heavily doped semiconductors and semimetals	275
9. The III-V compounds	277
10. Magnetically ordered semiconductors	279
11. Peltier and Ettingshausen cooling devices	279
11.1. Introduction	279
11.2. The Ettingshausen cooling device—performance	280
11.3. Microscopic theory of the Ettingshausen cooler	281
11.4. Experimental cooling devices	284
11.5. Magneto-Peltier cooling	284
Acknowledgments	285
References	285

The direct observation of imperfections in crystals

D. W. PASHLEY

Tube Investments Research Laboratories, Hinxton Hall, Cambridge

Contents

	Page
1. Historical introduction	292
2. The geometrical properties of lattice imperfections	295
2.1. The dislocation line	295
2.2. Stacking faults and partial dislocations	296
2.3. Vacancies and the geometry of dislocation loops	298
2.4. The strain field around dislocations	299
2.5. Dislocation interactions and dislocation arrays	299
2.6. Dislocation sources	300
3. Optical methods for observing lattice imperfections	301
3.1. Growth spirals	301
3.2. Etching techniques	302
3.3. Decoration methods	303
3.4. Birefringence methods	304
4. The electron microscope methods	304
4.1. Diffraction contrast	305
4.2. Determination of Burgers vectors	310
4.3. Stacking faults and anti-phase boundaries	311
4.4. Point defect aggregates	312
4.5. Dislocation networks and arrays	314
4.6. Stacking fault energies	315
4.7. Directly resolved periodic structures	315
4.8. Moiré patterns	316
4.9. Imperfections in periodic images	317
4.10. Applications of periodic images	318
5. X-ray methods	319
5.1. The Berg-Barrett method	319
5.2. The Lang methods	320
5.3. Quantitative information on strain fields of dislocations	321
5.4. Anomalous transmission techniques	322
6. Field ion microscopy	323
6.1. The instrument and its operation	323
6.2. The detection of vacancies	324
6.3. The study of dislocations	324
7. Summary and discussion	325
Acknowledgments	327
References	327

Some effects of point defects on the vibrations of crystal lattices†

A. A. MARADUDIN

Westinghouse Research Laboratories, Pittsburgh, Pennsylvania 15235, U.S.A.

Contents

	Page
1. Introduction	332
2. General theory of the effects of point defects on the dynamical properties of crystals	335
2.1. Time-independent defect problems	335
2.1.1. General properties of the atomic force constants in perturbed crystals	336
2.1.2. Solution of the equations of motion for a perturbed crystal	340
2.1.3. The dynamical matrix for a perturbed crystal	342
2.1.4. An alternative formulation of the eigenvalue problem for a perturbed crystal	343
2.1.5. The nature of the vibration modes in an imperfect crystal	345
2.1.6. The frequency spectrum of a perturbed crystal and resonance modes	347
2.1.7. Additive functions of normal mode frequencies	349
2.1.8. The Green's function for a perturbed crystal	350
2.1.9. Examples	351
2.2. Time-dependent position and momentum correlation functions	358
2.2.1. Expressions for correlation functions in perturbed crystals	358
2.2.2. Symmetry properties of correlation functions	364
2.3. The scattering of lattice waves by point defects	364
2.4. Defects with internal degrees of freedom	367
2.5. The use of symmetry and group theory in lattice dynamical defect problems	369
Acknowledgments	378
References	378

X-ray microscopy

V. E. COSSLETT

Cavendish Laboratory, University of Cambridge

Contents

	Page
1. Introduction	381
2. Reflection x-ray microscopy	382
3. Contact microradiography	385
3.1. Principles	385
3.2. Applications	387
4. The projection x-ray microscope	388
4.1. Principles	388
4.2. Resolving power	389
4.3. Related methods of x-ray microscopy	391
4.4. Applications of the x-ray projection microscope	393
5. X-ray scanning microscopy	394
5.1. Principles	394
5.2. Design, construction and operation	397
5.3. Performance and limitations	398
5.4. Applications of the scanning x-ray microscope and micro-analyser	403
6. Conclusion	405
Acknowledgments	405
References	405

Astrophysical neutrinos

M. A. RUDERMAN†

Department of Physics, New York University, New York, N.Y.

Contents

	Page
1. Introduction	412
2. Neutrinos as a stellar probe	414
2.1. The solar neutrino spectrum	414
2.2. The detection of solar neutrinos	417
2.3. Neutrinos from nuclear β -decay processes in highly evolved stars	420
2.4. URCA processes	420
2.5. Terrestrial neutrinos	424
3. Astrophysics as a test of neutrino properties	425
3.1. Electromagnetic properties of neutrinos	425
3.2. The electron-neutrino interaction	428
3.3. Neutrino emissivities from stellar interiors	430
3.4. Effects of the neutrino pair emission on stellar evolution	436
3.5. The testimony of isotopic abundances	442
3.6. Supernovae and neutrino emission	446
4. Neutrino fluxes in the universe	449
4.1. Cosmological limits	449
4.2. Neutrino emission from known sources	452
4.3. Speculative neutrino densities	453
4.4. Experimental limits	455
4.5. Prospects	457
References	460

Solid-state polymerization induced by radiation

A. CHARLESBY

Royal Military College of Science, Shrivenham, Swindon, Wilts.

Contents

	Page
1. Introduction	464
2. Early work	467
3. Reaction mechanisms in radiation-induced polymerization	469
4. Oriented polymer crystals	473
5. Monomer orientation during polymerization	481
6. Explosive post-radiation polymerization	485
7. Effect of phase change on post-radiation polymerization	488
8. Polymerization associated with crystal defects	491
9. Effect of pressure	496
10. Polymerization rates of metal acrylates	498
11. Orientation of monomer units along the polymer	499
12. Polymorphism	501
13. Other monomers	502
14. General characteristics of solid-state polymerization	504
14.1. Discussion	504
14.2. Monomer reactivity in solid and liquid	504
14.3. Reaction kinetics	504
14.4. Monomer orientation within the solid	505
14.5. Polymerization at very low temperatures	507
14.6. Post-radiation polymerization	508
15. Conclusions	509
Appendix	510
Analysis of limiting polymerization	510
Post-radiation oriented polymerization	512
Acknowledgments	514
References	514