

CONTENTS

	PAGE
PREFACE	iv
Applications of Quantum Mechanics in Theoretical Chemistry. By G. G. HALL	1
Progress in Vacuum Technology. By J. POLLARD	33
The Propagation of Elastic Waves in Crystals and other Anisotropic Media. By M. J. P. MUSGRAVE	74
Relativity. By H. BONDI	97
Double Beta Decay. By H. PRIMAKOFF and S. P. ROSEN	121
Physical Problems of Thermoelectricity. By A. F. JOFFE and L. S. STIL'BANS	167
Paramagnetic Resonance Data. By J. W. ORTON	204
Experimental Investigations of the Ionospheric E-Layer. By B. J. ROBINSON	241
Radio-frequency Spectroscopy of Excited Atoms. By G. W. SERIES	280
The Theory of a Fermi Liquid. By A. A. ABRIKOSOV and I. M. KHALATNIKOV	329
Invariance in Elementary Particle Physics. By N. KEMMER, J. C. POLKINGHORNE and D. L. PURSEY	368
Nuclear Magnetism in Pure Liquids. By J. G. POWLES	433
Experimental Work with ^3He . By V. P. PESHKOV and K. N. ZINOV'EVA	504
The Two-Nucleon Interaction. By R. J. N. PHILLIPS	562

APPLICATIONS OF QUANTUM MECHANICS IN THEORETICAL CHEMISTRY

By G. G. HALL†

Quantum Chemistry Group, University of Uppsala, Uppsala, Sweden

CONTENTS

	PAGE
§ 1. Introduction.....	2
1.1. Survey of quantum mechanics as used in theoretical chemistry	2
1.2. The mathematical background.....	3
1.3. Different methods of applying quantum mechanics.....	4
§ 2. The calculation method : ' solving the Schrödinger equation '.....	5
2.1. The molecular orbital method.....	5
2.2. More accurate methods.....	6
2.3. The accurate solution as a series of determinants.....	7
2.4. The choice of atomic orbitals.....	10
2.4.1. Hydrogen-like functions.....	10
2.4.2. Atomic self-consistent field functions.....	10
2.4.3. Laguerre functions.....	11
2.4.4. Slater functions.....	11
2.4.5. Dirichlet functions.....	11
2.4.6. Gaussian functions.....	11
2.5. Survey of results and comparison with experiment.....	11
2.6. Influence of electronic computers.....	13
§ 3. The method of parameters : ' allowing experiment to help theory '....	14
3.1. The problem of large molecules.....	14
3.2. Empirical parameters in the molecular orbital equations.....	15
3.3. The molecular orbital theory of conjugated molecules.....	18
3.4. Pitfalls and safeguards.....	22
§ 4. The method of models : ' simplifying the problem '.....	23
4.1. The use of models.....	23
4.2. Various models.....	24
4.2.1. The free electron model.....	24
4.2.2. The valence bond theory.....	25
4.2.3. Atoms in molecules.....	25
4.2.4. Ligand field theory.....	26
4.2.5. The electrostatic method.....	26
4.2.6. Ionic molecules.....	26
§ 5. The present situation.....	27
5.1. Appreciation of the three approaches.....	27
5.2. Some objectives of current research.....	28
5.3. Wider implications.....	29
Acknowledgments.....	30
References.....	30

† Permanent address : Department of Mathematics, Imperial College, London.

PROGRESS IN VACUUM TECHNOLOGY

By J. POLLARD

Services Electronics Research Laboratory, Baldock, Herts.

CONTENTS

	PAGE
§ 1. Introduction.....	34
§ 2. Mechanical pumps	35
2.1. Rotary backing pumps.....	35
2.2. Positive displacement rotary compressors.....	36
§ 3. Vapour pumps.....	38
3.1. Condensation pump theory.....	38
3.2. Oil condensation pumps	41
3.3. Mercury condensation pumps.....	42
3.4. Ejector pumps.....	43
§ 4. Vapour traps	44
4.1. Conduction cooled traps	44
4.2. Refrigerated baffle traps.....	45
4.3. Traps for oil-pumped systems	46
§ 5. Gettering and ionization pumps.....	46
5.1. Gettering pumps.....	46
5.2. Ionization pumps	51
§ 6. Measurement of pumping speed.....	52
§ 7. Measurement of pressure.....	53
7.1. Mechanical gauges	53
7.2. Acoustic gauges.....	55
7.3. Thermal conductivity gauges	55
7.4. Knudsen type gauges.....	56
7.5. Radioactive ionization gauges.....	57
7.6. Measurement of very low pressures.....	57
§ 8. Very low pressure techniques.....	62
§ 9. Newer mass spectrometers for vacuum systems.....	64
9.1. The omegatron.....	64
9.2. The linear R.F. spectrometer.....	66
9.3. The time-of-flight mass spectrometer.....	67
§ 10. Leak detection.....	67
10.1. Detectors using ordinary vacuum gauges.....	68
10.2. Detectors employing special properties of the search gas....	68
10.3. Mass spectrometer methods.....	69
10.4. Performance of leak detecting systems.....	69
§ 11. Conclusion.....	71
References	71

THE PROPAGATION OF ELASTIC WAVES IN CRYSTALS AND OTHER ANISOTROPIC MEDIA

By M. J. P. MUSGRAVE

National Physical Laboratory, Teddington, Middlesex

CONTENTS

	PAGE
§ 1. Introduction	75
§ 2. General exposition	75
2.1. Velocity, inverse (slowness) and wave surfaces	75
2.2. Generalized Hooke's law	76
2.3. Equations of motion	78
2.4. Plane waves	78
2.5. General characteristics of propagation	80
§ 3. Media of various symmetries	81
3.1. Hexagonal symmetry	81
3.2. Calculated characteristics of propagation	82
3.3. Experimentally observed characteristics of propagation	86
§ 4. Reflection and refraction	88
4.1. Boundary conditions at a plane interface	88
4.2. Critical angles and surface waves	88
4.3. Determination of possible reflected and refracted waves	89
§ 5. Surface waves of Rayleigh and Love type	90
5.1. General discussion	90
5.2. Hexagonal and cubic media	91
5.3. Monoclinic and orthorhombic media	91
§ 6. Stationary waves	92
§ 7. Propagation of elastic waves in polycrystalline aggregates	92
7.1. Relation of single crystal to the aggregate	92
7.2. Elastic anisotropy due to preferred orientation	93
7.3. Elastic anisotropy due to laminated structure	93
7.4. Problems of attenuation	94
§ 8. Relation between theory and experiment	94
Acknowledgments	95
References	95

RELATIVITY

By H. BONDI

University of London, King's College

CONTENTS

	PAGE
PART I: SPECIAL RELATIVITY	
§ 1. Newtonian relativity.....	97
§ 2. The special principle of relativity.....	99
§ 3. Space-time.....	101
§ 4. Relativistic dynamics.....	103
§ 5. The status of special relativity.....	105
PART II: GENERAL RELATIVITY	
§ 1. Newtonian gravitation.....	106
§ 2. The principle of equivalence.....	107
§ 3. Riemannian formulation.....	108
§ 4. The general theory of relativity.....	110
§ 5. Modern developments.....	113
5.1. Conservation laws.....	113
5.2. Equations of motion.....	114
5.3. Gravitational waves.....	116
5.4. The Hamiltonian formulation and quantization.....	117
5.5. Cosmology.....	117
5.6. Electromagnetism.....	118
Acknowledgments.....	119
References.....	119

DOUBLE BETA DECAY

BY H. PRIMAKOFF AND S. P. ROSEN

Department of Physics, Washington University, St. Louis, Missouri, U.S.A.

CONTENTS

	PAGE
§ 1. Introduction.....	121
§ 2. Discussion of experimental evidence.....	127
§ 3. Theory of $\beta\beta$ decay.....	136
3.1. Nucleon-lepton interaction.....	136
3.2. Single β^\mp decay.....	140
3.3. General formulation of the $\beta^\mp\beta^\mp$ decay transition probability amplitude.....	143
3.4. No-neutrino $\beta^\mp\beta^\mp$ decay.....	143
3.5. Two-neutrino $\beta^\mp\beta^\mp$ decay.....	152
3.6. $\beta\beta$ decays with orbital negatron capture.....	160
3.7. Relation of $\beta\beta$ decay to inverse β decay.....	160
§ 4. Comparison of experimental and theoretical $\beta\beta$ half-lives.....	162
§ 5. Conclusion.....	163
Acknowledgments.....	164
References.....	164

PHYSICAL PROBLEMS OF THERMOELECTRICITY

By A. F. JOFFE AND L. S. STIL'BANS

Academy of Sciences, Leningrad, U.S.S.R.

Translated by M. G. Priestley

CONTENTS

	PAGE
§ 1. Introduction.....	168
§ 2. The efficiency of thermoelectric generators of electricity, refrigerators and heaters.....	168
§ 3. The conditions for the optimum figure-of-merit of thermoelements.....	170
3.1. Mobility and effective mass.....	172
3.2. Thermal conductivity.....	174
3.3. The thermoelectric properties of solid solutions.....	180
§ 4. Establishment of the optimum carrier concentration.....	185
§ 5. Additional factors relating to the thermal e.m.f.....	188
§ 6. The scattering mechanisms of the charge carriers.....	194
6.1. The scattering of electrons by thermal vibrations of the lattice	194
6.2. The scattering of electrons in solid solutions.....	199
6.3. The investigation of the mechanism of scattering by ionized impurities.....	200
References	203

EXPERIMENTAL INVESTIGATIONS OF THE IONOSPHERIC E-LAYER

By B. J. ROBINSON

Radiophysics Laboratory, C.S.I.R.O., Sydney, Australia†

CONTENTS

	PAGE
§ 1. Introduction.....	242
§ 2. Early investigations.....	242
§ 3. Routine penetration-frequency measurements	246
3.1. Identification of the penetration frequency.....	246
3.2. Diurnal variation of the penetration frequency.....	248
3.3. Variation of penetration frequency with solar activity.....	251
3.4. Seasonal variation of the penetration frequency.....	253
3.5. Variation of the penetration frequency with latitude.....	254
3.6. Influence of the magnetic current system.....	255
3.7. Other influences	257
§ 4. Measurements of the height of the E-layer.....	257
4.1. Routine measurements of group height.....	257
4.2. Special measurements	259
§ 5. Determination of the distribution of free electrons.....	260
§ 6. Direct measurements in the E-region using rockets.....	262
§ 7. The fine structure of the E-layer.....	264
§ 8. Behaviour of the E-layer during eclipses.....	268
§ 9. The effect of solar flares on the E-layer.....	269
§ 10. Formation of the E-layer.....	271
§ 11. Concluding remarks	275
Acknowledgments.....	276
References	276

RADIO-FREQUENCY SPECTROSCOPY OF EXCITED ATOMS

By G. W. SERIES

Clarendon Laboratory, Oxford

CONTENTS

	PAGE
§ 1. Introduction	280
1.1. Precision of measurement	280
1.2. Stimulated transitions and conditions of observation	281
1.3. Types of experiment	282
§ 2. Time-independent theory	285
2.1. Stationary state theory of hyperfine structure	285
2.2. Calculation of the nuclear moments	287
§ 3. Time-dependent theory	289
3.1. Simple model for the radio-frequency transitions	289
3.2. Violation of the simplifying assumptions	291
3.3. Multiplicity of energy levels	292
3.4. Finite life of excited states	294
3.5. Transitions between excited states in the vicinity of other states	297
3.6. Quanta of different kinds	298
§ 4. Double resonance experiments	299
4.1. Resonance radiation	299
4.2. Spatial distribution of resonance radiation: classical model	300
4.3. Intensity and polarization of resonance radiation: quantum theory	301
4.4. Double resonance experiments in magnetic fields	305
4.5. Double resonance experiments in zero magnetic field	311
4.6. Excitation by unpolarized light in zero magnetic field	314
4.7. Double resonance measurements of isotope shifts	316
4.8. Detection by coincidence of photons in cascade	317
§ 5. Excitation by electron impact	317
5.1. Selective excitation of different states within a given term	319
5.2. Selective excitation of different terms	321
§ 6. Atomic beam experiments	323
§ 7. Table of measurements	325
Acknowledgments	327
References	327

THE THEORY OF A FERMI LIQUID

(THE PROPERTIES OF LIQUID ^3He AT LOW TEMPERATURES)

BY A. A. ABRIKOSOV AND I. M. KHALATNIKOV

Institute for Physical Problems, Moscow

Translated by M. G. Priestley

CONTENTS

	PAGE
§ 1. Introduction	330
§ 2. The energy of excitations	331
§ 3. Effective mass.....	332
§ 4. Specific heat and entropy	333
§ 5. Magnetic susceptibility.....	334
§ 6. Kinetic equation	336
§ 7. Viscosity	337
§ 8. Thermal conductivity.....	341
§ 9. Sound.....	343
§ 10. Dispersion and absorption of sound	348
§ 11. Light scattering (fluctuations in the distribution function).....	352
Appendix: The microscopic theory of a Fermi liquid	358
1. A rarefied Fermi gas.....	358
2. The microscopic theory of a Fermi liquid at $T = 0$	362
References.....	366

INVARIANCE IN ELEMENTARY PARTICLE PHYSICS

BY N. KEMMER, J. C. POLKINGHORNE[†] AND D. L. PURSEY

Tait Institute of Mathematical Physics, University of Edinburgh

CONTENTS

	PAGE
§ 1. Introduction.....	369
§ 2. Invariance principles and conservation laws.....	371
§ 3. Rotations and Lorentz transformations.....	374
3.1. Rotations in three dimensions.....	374
3.2. Rotations in four dimensions.....	376
3.3. Lorentz transformations.....	378
§ 4. Gauge transformations.....	380
4.1. Gauge transformations in electrodynamics.....	380
4.2. Conservation of baryons and leptons.....	384
§ 5. Space inversion, charge conjugation and time reversal.....	385
5.1. Space inversion.....	385
5.2. Charge conjugation.....	390
5.3. Time reversal.....	395
5.4. The <i>CPT</i> theorem.....	400
5.5. Tests of invariance, and determination of intrinsic parities....	402
§ 6. Isobaric spin (nucleons and pions).....	407
6.1. Nucleons.....	407
6.2. Pions and nucleons.....	410
6.3. Invariance of interaction.....	412
6.4. Application to scattering.....	414
§ 7. Isobaric spin (strange particles).....	416
7.1. Associated production and the Gell-Mann–Nishijima scheme	416
7.2. Mathematical formulations of the Gell-Mann–Nishijima scheme	421
7.3. Global symmetry.....	423
7.4. Electric charge.....	426
§ 8. Conclusion.....	427
Appendix : Form invariance.....	428

NUCLEAR MAGNETISM IN PURE LIQUIDS

By J. G. POWLES

Physics Department, Queen Mary College (University of London)

CONTENTS

	PAGE
§ 1. Introduction	433
§ 2. Magnetic shielding effects in steady state spectra	439
2.1. Introduction	439
2.2. Magnetic shielding in atoms	441
2.3. Magnetic shielding in molecules	442
2.3.1. Perturbation methods	442
2.3.2. Variational methods	446
2.3.3. Circulating currents	449
2.3.4. Intermolecular effects	452
2.3.5. Intramolecular effects	455
2.3.6. Anisotropy relaxation	457
2.3.7. Chemical structure and analysis	458
§ 3. Indirect spin-spin interactions in steady state spectra	460
3.1. Introduction	460
3.2. Phenomenological explanation	463
3.3. The physical origin of indirect spin-spin coupling	470
3.4. Missing multiplets	477
3.5. Double resonance in high resolution spectra	478
3.6. Analysis of complex spectra	481
3.7. Multiple quantum transitions	484
3.8. Natural line widths	488
§ 4. Magnetic shielding and indirect spin-spin interaction effects in transient experiments	489
4.1. Introduction	489
4.2. Decay signals	489
4.3. Echoes	494
References	499

EXPERIMENTAL WORK WITH ^3He

BY V. P. PESHKOV AND K. N. ZINOV'EVA

Institute for Physical Problems, Moscow

CONTENTS

	PAGE
§ 1. Methods of separation of ^3He	504
§ 2. Saturated vapour pressure. Critical point.....	515
§ 3. Equation of state of gaseous ^3He	517
§ 4. Thermomolecular pressure ratios for ^3He	521
§ 5. Melting curve and α - β transition in solid ^3He	521
§ 6. Density of liquid, gaseous and solid ^3He	525
§ 7. Latent heat of vaporization.....	529
§ 8. Specific heat.....	530
§ 9. Entropy.....	532
§ 10. Magnetic properties of ^3He	536
§ 11. Absence of superfluidity.....	540
§ 12. Viscosity.....	541
§ 13. Thermoconductivity.....	545
§ 14. Temperature discontinuity on the boundary of ^3He and the wall.....	547
§ 15. Surface tension.....	547
§ 16. Velocity of sound.....	548
§ 17. Compressibility of ^3He	550
§ 18. Adsorption.....	551
§ 19. Cryostats with ^3He	552
§ 20. Production of low temperatures by crystallization of ^3He	557
§ 21. Conclusion.....	558
Acknowledgments.....	558
References.....	559

THE TWO-NUCLEON INTERACTION

By R. J. N. PHILLIPS

Atomic Energy Research Establishment, Harwell, Berks

CONTENTS

	PAGE
§ 1. General introduction	563
§ 2. Phenomenology	564
2.1. Introduction	564
2.2. The form of the potential	565
2.3. The description of scattering	567
2.4. Analysis in terms of potentials	571
2.4.1. Evidence from the deuteron	571
2.4.2. Evidence from other nuclei	572
2.4.3. Low-energy scattering	574
2.4.4. High-energy scattering	577
2.4.5. Other experiments	581
2.4.6. Spin-orbit coupling	583
2.4.7. Separable potentials	584
2.5. The boundary condition model	584
2.6. Phase-shift analysis	586
2.7. The construction of potentials from phase shifts	591
2.8. The Gammel-Thaler potential	594
2.9. Outlook	597
§ 3. Meson field theory	597
3.1. Introduction	597
3.2. The construction of a potential	599
3.2.1. The canonical transformation method	599
3.2.2. The \mathcal{S} -matrix method	602
3.2.3. The Tamm-Dancoff method	603
3.2.4. The Lévy-Klein method	606
3.2.5. The Brueckner-Watson method	608
3.2.6. Uniqueness	609
3.3. Potentials from the pion field	610
3.3.1. The pion field	610
3.3.2. The form of the potential	612
3.3.3. The phenomenological inner region	613
3.3.4. The one-pion exchange potential	613
3.3.5. The two-pion exchange potential	614
3.3.6. Static potential models	616
3.3.7. Correction terms	620
3.3.8. Pair suppression	623
3.3.9. Spin-orbit coupling	624
3.3.10. The Signell-Marshak potential	625
3.3.11. Dispersion relations	626
3.4. Outlook	627
Acknowledgments	627
References	627

