

Contents

Preface	v
Contributors	xxiii
 Part I Mechanics	 1
1 Kinematics	3
1.1 Description of motion	3
1.1.1 Reference systems	3
1.1.2 Time	8
1.1.3 Length, area, volume	9
1.1.4 Angle	11
1.1.5 Mechanical systems	12
1.2 Motion in one dimension	14
1.2.1 Velocity	14
1.2.2 Acceleration	17
1.2.3 Simple motion in one dimension	19
1.3 Motion in several dimensions	22
1.3.1 Velocity vector	23
1.3.2 Acceleration vector	25
1.3.3 Free-fall and projectile motion	28
1.4 Rotational motion	31
1.4.1 Angular velocity	32
1.4.2 Angular acceleration	33
1.4.3 Orbital velocity	34
 2 Dynamics	 37
2.1 Fundamental laws of dynamics	37
2.1.1 Mass and momentum	37
2.1.2 Newton's laws	40
2.1.3 Orbital angular momentum	48
2.1.4 Torque	50
2.1.5 The fundamental law of rotational dynamics	52

2.2	Forces	53
2.2.1	Weight	53
2.2.2	Spring torsion forces	54
2.2.3	Frictional forces	56
2.3	Inertial forces in rotating reference systems	59
2.3.1	Centripetal and centrifugal forces	60
2.3.2	Coriolis force	62
2.4	Work and energy	63
2.4.1	Work	63
2.4.2	Energy	65
2.4.3	Kinetic energy	66
2.4.4	Potential energy	67
2.4.5	Frictional work	70
2.5	Power	70
2.5.1	Efficiency	71
2.6	Collision processes	72
2.6.1	Elastic straight-line central collisions	74
2.6.2	Elastic off-center central collisions	76
2.6.3	Elastic non-central collision with a body at rest	76
2.6.4	Inelastic collisions	78
2.7	Rockets	79
2.7.1	Thrust	79
2.7.2	Rocket equation	81
2.8	Systems of point masses	82
2.8.1	Equations of motion	82
2.8.2	Momentum conservation law	84
2.8.3	Angular momentum conservation law	85
2.8.4	Energy conservation law	86
2.9	Lagrange's and Hamilton's equations	86
2.9.1	Lagrange's equations and Hamilton's principle	86
2.9.2	Hamilton's equations	89
3	Rigid bodies	93
3.1	Kinematics	93
3.1.1	Density	93
3.1.2	Center of mass	94
3.1.3	Basic kinematic quantities	96
3.2	Statics	97
3.2.1	Force vectors	98
3.2.2	Torque	100
3.2.3	Couples	101
3.2.4	Equilibrium conditions of statics	103
3.2.5	Technical mechanics	104
3.2.6	Machines	106
3.3	Dynamics	111
3.4	Moment of inertia and angular momentum	111
3.4.1	Moment of inertia	111
3.4.2	Angular momentum	116
3.5	Work, energy and power	118
3.5.1	Kinetic energy	119
3.5.2	Torsional potential energy	120

3.6	Theory of the gyroscope	121
3.6.1	Tensor of inertia	121
3.6.2	Nutation and precession	124
3.6.3	Applications of gyroscopes	127
4	Gravitation and the theory of relativity	129
4.1	Gravitational field	129
4.1.1	Law of gravitation	129
4.1.2	Planetary motion	131
4.1.3	Planetary system	133
4.2	Special theory of relativity	137
4.2.1	Principle of relativity	137
4.2.2	Lorentz transformation	140
4.2.3	Relativistic effects	144
4.2.4	Relativistic dynamics	145
4.3	General theory of relativity and cosmology	148
4.3.1	Stars and galaxies	150
5	Mechanics of continuous media	153
5.1	Theory of elasticity	153
5.1.1	Stress	153
5.1.2	Elastic deformation	156
5.1.3	Plastic deformation	167
5.2	Hydrostatics, aerostatics	171
5.2.1	Liquids and gases	172
5.2.2	Pressure	172
5.2.3	Buoyancy	180
5.2.4	Cohesion, adhesion, surface tension	183
5.3	Hydrodynamics, aerodynamics	186
5.3.1	Flow field	186
5.3.2	Basic equations of ideal flow	187
5.3.3	Real flow	197
5.3.4	Turbulent flow	203
5.3.5	Scaling laws	206
5.3.6	Flow with density variation	209
6	Nonlinear dynamics, chaos and fractals	211
6.1	Dynamical systems and chaos	212
6.1.1	Dynamical systems	212
6.1.2	Conservative systems	217
6.1.3	Dissipative systems	219
6.2	Bifurcations	221
6.2.1	Logistic mapping	222
6.2.2	Universality	225
6.3	Fractals	225
	Formula symbols used in mechanics	229
7	Tables on mechanics	231
7.1	Density	231
7.1.1	Solids	231
7.1.2	Fluids	237
7.1.3	Gases	238

7.2	Elastic properties	239
7.3	Dynamical properties	243
7.3.1	Coefficients of friction	243
7.3.2	Compressibility	244
7.3.3	Viscosity	248
7.3.4	Flow resistance	250
7.3.5	Surface tension	251
Part II	Vibrations and Waves	253
8	Vibrations	255
8.1	Free undamped vibrations	257
8.1.1	Mass on a spring	258
8.1.2	Standard pendulum	260
8.1.3	Physical pendulum	263
8.1.4	Torsional vibration	265
8.1.5	Liquid pendulum	266
8.1.6	Electric circuit	267
8.2	Damped vibrations	268
8.2.1	Friction	269
8.2.2	Damped electric oscillator circuit	273
8.3	Forced vibrations	275
8.4	Superposition of vibrations	277
8.4.1	Superposition of vibrations of equal frequency	277
8.4.2	Superposition of vibrations of different frequencies	279
8.4.3	Superposition of vibrations in different directions and with different frequencies	280
8.4.4	Fourier analysis, decomposition into harmonics	282
8.5	Coupled vibrations	283
9	Waves	287
9.1	Basic features of waves	287
9.2	Polarization	293
9.3	Interference	294
9.3.1	Coherence	294
9.3.2	Interference	295
9.3.3	Standing waves	296
9.3.4	Waves with different frequencies	299
9.4	Doppler effect	300
9.4.1	Mach waves and Mach shock waves	302
9.5	Refraction	302
9.6	Reflection	304
9.6.1	Phase relations	304
9.7	Dispersion	305
9.8	Diffraction	305
9.8.1	Diffraction by a slit	306
9.8.2	Diffraction by a grating	307
9.9	Modulation of waves	308
9.10	Surface waves and gravity waves	309

10 Acoustics	311
10.1 Sound waves	311
10.1.1 Sound velocity	311
10.1.2 Parameters of sound	313
10.1.3 Relative quantities	317
10.2 Sources and receivers of sound	319
10.2.1 Mechanical sound emitters	319
10.2.2 Electro-acoustic transducers	321
10.2.3 Sound absorption	324
10.2.4 Sound attenuation	327
10.2.5 Flow noise	328
10.3 Ultrasound	328
10.4 Physiological acoustics and hearing	329
10.4.1 Perception of sound	330
10.4.2 Evaluated sound levels	331
10.5 Musical acoustics	331
11 Optics	335
11.1 Geometric optics	337
11.1.1 Optical imaging—fundamental concepts	338
11.1.2 Reflection	341
11.1.3 Refraction	345
11.2 Lenses	358
11.2.1 Thick lenses	358
11.2.2 Thin lenses	364
11.3 Lens systems	364
11.3.1 Lenses with diaphragms	365
11.3.2 Image defects	366
11.4 Optical instruments	368
11.4.1 Pinhole camera	369
11.4.2 Camera	369
11.4.3 Eye	370
11.4.4 Eye and optical instruments	372
11.5 Wave optics	376
11.5.1 Scattering	376
11.5.2 Diffraction and limitation of resolution	377
11.5.3 Refraction in the wave picture	379
11.5.4 Interference	380
11.5.5 Diffractive optical elements	384
11.5.6 Dispersion	389
11.5.7 Spectroscopic apparatus	390
11.5.8 Polarization of light	391
11.6 Photometry	395
11.6.1 Photometric quantities	396
11.6.2 Photometric quantities	403
Symbols used in formulae on vibrations, waves, acoustics and optics	407
12 Tables on vibrations, waves, acoustics and optics	409
12.1 Tables on vibrations and acoustics	409
12.2 Tables on optics	414

Part III Electricity	419
13 Charges and currents	421
13.1 Electric charge	421
13.1.1 Coulomb's law	423
13.2 Electric charge density	424
13.3 Electric current	426
13.3.1 Ampere's law	428
13.4 Electric current density	428
13.4.1 Electric current flow field	430
13.5 Electric resistance and conductance	431
13.5.1 Electric resistance	431
13.5.2 Electric conductance	432
13.5.3 Resistivity and conductivity	432
13.5.4 Mobility of charge carriers	433
13.5.5 Temperature dependence of the resistance	434
13.5.6 Variable resistors	435
13.5.7 Connection of resistors	436
14 Electric and magnetic fields	439
14.1 Electric field	439
14.2 Electrostatic induction	440
14.2.1 Electric field lines	441
14.2.2 Electric field strength of point charges	444
14.3 Force	445
14.4 Electric voltage	445
14.5 Electric potential	447
14.5.1 Equipotential surfaces	448
14.5.2 Field strength and potential of various charge distributions	448
14.5.3 Electric flux	451
14.5.4 Electric displacement in a vacuum	453
14.6 Electric polarization	454
14.6.1 Dielectric	456
14.7 Capacitance	457
14.7.1 Parallel-plate capacitor	458
14.7.2 Parallel connection of capacitors	458
14.7.3 Series connection of capacitors	459
14.7.4 Capacitance of simple arrangements of conductors	459
14.8 Energy and energy density of the electric field	460
14.9 Electric field at interfaces	461
14.10 Magnetic field	462
14.11 Magnetism	463
14.11.1 Magnetic field lines	463
14.12 Magnetic flux density	465
14.13 Magnetic flux	467
14.14 Magnetic field strength	469
14.15 Magnetic potential difference and magnetic circuits	470
14.15.1 Ampere's law	472
14.15.2 Biot–Savart's law	474
14.15.3 Magnetic field of a rectilinear conductor	476
14.15.4 Magnetic fields of various current distributions	477

14.16	Matter in magnetic fields	478
14.16.1	Diamagnetism	480
14.16.2	Paramagnetism	480
14.16.3	Ferromagnetism	481
14.16.4	Antiferromagnetism	483
14.16.5	Ferrimagnetism	484
14.17	Magnetic fields at interfaces	484
14.18	Induction	485
14.18.1	Faraday's law of induction	486
14.18.2	Transformer induction	487
14.19	Self-induction	488
14.19.1	Inductances of geometric arrangements of conductors	490
14.19.2	Magnetic conductance	491
14.20	Mutual induction	492
14.20.1	Transformer	493
14.21	Energy and energy density of the magnetic field	494
14.22	Maxwell's equations	496
14.22.1	Displacement current	497
14.22.2	Electromagnetic waves	498
14.22.3	Poynting vector	500
15	Applications in electrical engineering	501
15.1	Direct-current circuit	502
15.1.1	Kirchhoff's laws for direct-current circuit	503
15.1.2	Resistors in a direct-current circuit	503
15.1.3	Real voltage source	505
15.1.4	Power and energy in the direct-current circuit	507
15.1.5	Matching for power transfer	508
15.1.6	Measurement of current and voltage :	509
15.1.7	Resistance measurement by means of the compensation method	510
15.1.8	Charging and discharging of capacitors	511
15.1.9	Switching the current on and off in a RL -circuit	513
15.2	Alternating-current circuit	514
15.2.1	Alternating quantities	514
15.2.2	Representation of sinusoidal quantities in a phasor diagram	517
15.2.3	Calculation rules for phasor quantities	519
15.2.4	Basics of alternating-current engineering	522
15.2.5	Basic components in the alternating-current circuit	529
15.2.6	Series connection of resistor and capacitor	534
15.2.7	Parallel connection of a resistor and a capacitor	535
15.2.8	Parallel connection of a resistor and an inductor	536
15.2.9	Series connection of a resistor and an inductor	536
15.2.10	Series-resonant circuit	538
15.2.11	Parallel-resonant circuit	539
15.2.12	Equivalence of series and parallel connections	541
15.2.13	Radio waves	542
15.3	Electric machines	544
15.3.1	Fundamental functional principle	544
15.3.2	Direct-current machine	545
15.3.3	Three-phase machine	547

16	Current conduction in liquids, gases and vacuum	551
16.1	Electrolysis	551
16.1.1	Amount of substance	551
16.1.2	Ions	552
16.1.3	Electrodes	552
16.1.4	Electrolytes	552
16.1.5	Galvanic cells	557
16.1.6	Electrokinetic effects	560
16.2	Current conduction in gases	560
16.2.1	Non-self-sustained discharge	560
16.2.2	Self-sustained gaseous discharge	563
16.3	Electron emission	565
16.3.1	Thermo-ionic emission	565
16.3.2	Photo emission	565
16.3.3	Field emission	566
16.3.4	Secondary electron emission	567
16.4	Vacuum tubes	567
16.4.1	Vacuum-tube diode	568
16.4.2	Vacuum-tube triode	568
16.4.3	Tetrode	571
16.4.4	Cathode rays	571
16.4.5	Channel rays	571
17	Plasma physics	573
17.1	Properties of a plasma	573
17.1.1	Plasma parameters	573
17.1.2	Plasma radiation	580
17.1.3	Plasmas in magnetic fields	581
17.1.4	Plasma waves	583
17.2	Generation of plasmas	586
17.2.1	Thermal generation of plasma	586
17.2.2	Generation of plasma by compression	586
17.3	Energy production with plasmas	588
17.3.1	MHD generator	588
17.3.2	Nuclear fusion reactors	589
17.3.3	Fusion with magnetic confinement	590
17.3.4	Fusion with inertial confinement	591
	Symbols used in formulae on electricity and plasma physics	593
18	Tables on electricity	595
18.1	Metals and alloys	595
18.1.1	Specific electric resistance	595
18.1.2	Electrochemical potential series	598
18.2	Dielectrics	601
18.3	Practical tables of electric engineering	606
18.4	Magnetic properties	609
18.5	Ferromagnetic properties	614
18.5.1	Magnetic anisotropy	617
18.6	Ferrites	619
18.7	Antiferromagnets	619
18.8	Ion mobility	620

Part IV	Thermodynamics	621
19	Equilibrium and state variables	623
19.1	Systems, phases and equilibrium	623
19.1.1	Systems	623
19.1.2	Phases	624
19.1.3	Equilibrium	625
19.2	State variables	627
19.2.1	State property definitions	627
19.2.2	Temperature	629
19.2.3	Pressure	634
19.2.4	Particle number, amount of substance and Avogadro number .	637
19.2.5	Entropy	640
19.3	Thermodynamic potentials	641
19.3.1	Principle of maximum entropy—principle of minimum energy	641
19.3.2	Internal energy as a potential	641
19.3.3	Entropy as a thermodynamic potential	642
19.3.4	Free energy	643
19.3.5	Enthalpy	644
19.3.6	Free enthalpy	647
19.3.7	Maxwell relations	648
19.3.8	Thermodynamic stability	649
19.4	Ideal gas	650
19.4.1	Boyle-Mariotte law	651
19.4.2	Law of Gay-Lussac	651
19.4.3	Equation of state	652
19.5	Kinetic theory of the ideal gas	653
19.5.1	Pressure and temperature	653
19.5.2	Maxwell-Boltzmann distribution	655
19.5.3	Degrees of freedom	657
19.5.4	Equipartition law	657
19.5.5	Transport processes	658
19.6	Equations of state	661
19.6.1	Equation of state of the ideal gas	661
19.6.2	Equation of state of real gases	665
19.6.3	Equation of states for liquids and solids	671
20	Heat, conversion of energy and changes of state	675
20.1	Energy forms	675
20.1.1	Energy units	675
20.1.2	Work	676
20.1.3	Chemical potential	677
20.1.4	Heat	678
20.2	Energy conversion	679
20.2.1	Conversion of equivalent energies into heat	679
20.2.2	Conversion of heat into other forms of energy	683
20.2.3	Exergy and anergy	683
20.3	Heat capacity	684
20.3.1	Total heat capacity	684
20.3.2	Molar heat capacity	686
20.3.3	Specific heat capacity	687

20.4	Changes of state	691
20.4.1	Reversible and irreversible processes	691
20.4.2	Isothermal processes	692
20.4.3	Isobaric processes	693
20.4.4	Isochoric processes	694
20.4.5	Adiabatic (isentropic) processes	695
20.4.6	Equilibrium states	697
20.5	Laws of thermodynamics	698
20.5.1	Zeroth law of thermodynamics	698
20.5.2	First law of thermodynamics	698
20.5.3	Second law of thermodynamics	701
20.5.4	Third law of thermodynamics	702
20.6	Carnot cycle	702
20.6.1	Principle and application	702
20.6.2	Reduced heat	705
20.7	Thermodynamic machines	706
20.7.1	Right-handed and left-handed processes	706
20.7.2	Heat pump and refrigerator	707
20.7.3	Stirling cycle	708
20.7.4	Steam engine	709
20.7.5	Open systems	710
20.7.6	Otto and Diesel engines	711
20.7.7	Gas turbines	713
20.8	Gas liquefaction	714
20.8.1	Generation of low temperatures	714
20.8.2	Joule–Thomson effect	715
21	Phase transitions, reactions and equalizing of heat	717
21.1	Phase and state of aggregation	717
21.1.1	Phase	717
21.1.2	Aggregation states	717
21.1.3	Conversions of aggregation states	718
21.1.4	Vapor	719
21.2	Order of phase transitions	720
21.2.1	First-order phase transition	720
21.2.2	Second-order phase transition	721
21.2.3	Lambda transitions	722
21.2.4	Phase-coexistence region	722
21.2.5	Critical indices	723
21.3	Phase transition and Van der Waals gas	724
21.3.1	Phase equilibrium	724
21.3.2	Maxwell construction	724
21.3.3	Delayed boiling and delayed condensation	726
21.3.4	Theorem of corresponding states	727
21.4	Examples of phase transitions	727
21.4.1	Magnetic phase transitions	727
21.4.2	Order–disorder phase transitions	728
21.4.3	Change in the crystal structure	729
21.4.4	Liquid crystals	730
21.4.5	Superconductivity	730
21.4.6	Superfluidity	731

21.5	Multicomponent gases	731
21.5.1	Partial pressure and Dalton's law	732
21.5.2	Euler equation and Gibbs–Duhem relation	733
21.6	Multiphase systems	734
21.6.1	Phase equilibrium	734
21.6.2	Gibbs phase rule	734
21.6.3	Clausius–Clapeyron equation	735
21.7	Vapor pressure of solutions	736
21.7.1	Raoult's law	736
21.7.2	Boiling-point elevation and freezing-point depression	736
21.7.3	Henry–Dalton law	738
21.7.4	Steam–air mixtures (humid air)	738
21.8	Chemical reactions	742
21.8.1	Stoichiometry	743
21.8.2	Phase rule for chemical reactions	744
21.8.3	Law of mass action	744
21.8.4	pH-value and solubility product	746
21.9	Equalization of temperature	748
21.9.1	Mixing temperature of two systems	748
21.9.2	Reversible and irreversible processes	749
21.10	Heat transfer	750
21.10.1	Heat flow	751
21.10.2	Heat transfer	751
21.10.3	Heat conduction	753
21.10.4	Thermal resistance	757
21.10.5	Heat transmission	759
21.10.6	Heat radiation	764
21.10.7	Deposition of radiation	764
21.11	Transport of heat and mass	766
21.11.1	Fourier's law	766
21.11.2	Continuity equation	766
21.11.3	Heat conduction equation	767
21.11.4	Fick's law and diffusion equation	768
21.11.5	Solution of the equation of heat conduction and diffusion	769

Formula symbols used in thermodynamics **771**

22 Tables on thermodynamics **775**

22.1	Characteristic temperatures	775
22.1.1	Units and calibration points	775
22.1.2	Melting and boiling points	777
22.1.3	Curie and Néel temperatures	786
22.2	Characteristics of real gases	787
22.3	Thermal properties of substances	788
22.3.1	Viscosity	788
22.3.2	Expansion, heat capacity and thermal conductivity	789
22.4	Heat transmission	795
22.5	Practical correction data	798
22.5.1	Pressure measurement	798
22.5.2	Volume measurements—conversion to standard temperature	803
22.6	Generation of liquid low-temperature baths	804

22.7	Dehydrators	805
22.8	Vapor pressure	806
22.8.1	Solutions	806
22.8.2	Relative humidity	806
22.8.3	Vapor pressure of water	807
22.9	Specific enthalpies	809

Part V Quantum physics 815

23 Photons, electromagnetic radiation and light quanta 817

23.1	Planck's radiation law	817
23.2	Photoelectric effect	820
23.3	Compton effect	822

24 Matter waves—wave mechanics of particles 825

24.1	Wave character of particles	825
24.2	Heisenberg's uncertainty principle	827
24.3	Wave function and observable	827
24.4	Schrödinger equation	835
24.4.1	Piecewise constant potentials	837
24.4.2	Harmonic oscillator	841
24.4.3	Pauli principle	843
24.5	Spin and magnetic moments	844
24.5.1	Spin	844
24.5.2	Magnetic moments	847

25 Atomic and molecular physics 851

25.1	Fundamentals of spectroscopy	851
25.2	Hydrogen atom	854
25.2.1	Bohr's postulates	855
25.3	Stationary states and quantum numbers in the central field	859
25.4	Many-electron atoms	864
25.5	X-rays	868
25.5.1	Applications of x-rays	870
25.6	Molecular spectra	871
25.7	Atoms in external fields	874
25.8	Periodic Table of elements	877
25.9	Interaction of photons with atoms and molecules	879
25.9.1	Spontaneous and induced emission	879

26 Elementary particle physics—standard model 883

26.1	Unification of interactions	883
26.1.1	Standard model	883
26.1.2	Field quanta or gauge bosons	887
26.1.3	Fermions and bosons	889
26.2	Leptons, quarks, and vector bosons	891
26.2.1	Leptons	891
26.2.2	Quarks	892
26.2.3	Hadrons	894
26.2.4	Accelerators and detectors	898

26.3	Symmetries and conservation laws	900
26.3.1	Parity conservation and the weak interaction	900
26.3.2	Charge conservation and pair production	901
26.3.3	Charge conjugation and antiparticles	902
26.3.4	Time-reversal invariance and inverse reactions	903
26.3.5	Conservation laws	903
26.3.6	Beyond the standard model	904
27	Nuclear physics	907
27.1	Constituents of the atomic nucleus	907
27.2	Basic quantities of the atomic nucleus	910
27.3	Nucleon-nucleon interaction	912
27.3.1	Phenomenologic nucleon-nucleon potentials	912
27.3.2	Meson exchange potentials	914
27.4	Nuclear models	915
27.4.1	Fermi-gas model	915
27.4.2	Nuclear matter	915
27.4.3	Droplet model	916
27.4.4	Shell model	917
27.4.5	Collective model	920
27.5	Nuclear reactions	922
27.5.1	Reaction channels and cross-sections	922
27.5.2	Conservation laws in nuclear reactions	926
27.5.3	Elastic scattering	928
27.5.4	Compound-nuclear reactions	929
27.5.5	Optical model	931
27.5.6	Direct reactions	931
27.5.7	Heavy-ion reactions	932
27.5.8	Nuclear fission	935
27.6	Nuclear decay	937
27.6.1	Decay law	938
27.6.2	α -decay	941
27.6.3	β -decay	943
27.6.4	γ -decay	946
27.6.5	Emission of nucleons and nucleon clusters	947
27.7	Nuclear reactor	947
27.7.1	Types of reactors	949
27.8	Nuclear fusion	950
27.9	Interaction of radiation with matter	953
27.9.1	Ionizing particles	953
27.9.2	γ -radiation	956
27.10	Dosimetry	958
27.10.1	Methods of dosage measurements	962
27.10.2	Environmental radioactivity	964
28	Solid-state physics	967
28.1	Structure of solid bodies	967
28.1.1	Basic concepts of solid-state physics	967
28.1.2	Structure of crystals	968
28.1.3	Bravais lattices	970
28.1.4	Methods for structure investigation	974
28.1.5	Bond relations in crystals	976

28.2	Lattice defects	979
28.2.1	Point defects	979
28.2.2	One-dimensional defects	981
28.2.3	Two-dimensional lattice defects	982
28.2.4	Amorphous solids	983
28.3	Mechanical properties of materials	984
28.3.1	Macromolecular solids	984
28.3.2	Compound materials	987
28.3.3	Alloys	988
28.3.4	Liquid crystals	990
28.4	Phonons and lattice vibrations	991
28.4.1	Elastic waves	991
28.4.2	Phonons and specific heat capacity	995
28.4.3	Einstein model	996
28.4.4	Debye model	997
28.4.5	Heat conduction	999
28.5	Electrons in solids	1000
28.5.1	Free-electron gas	1001
28.5.2	Band model	1007
28.6	Semiconductors	1011
28.6.1	Extrinsic conduction	1014
28.6.2	Semiconductor diode	1016
28.6.3	Transistor	1023
28.6.4	Unipolar (field effect) transistors	1030
28.6.5	Thyristor	1032
28.6.6	Integrated circuits (IC)	1034
28.6.7	Operational amplifiers	1037
28.7	Superconductivity	1042
28.7.1	Fundamental properties of superconductivity	1043
28.7.2	High-temperature superconductors	1047
28.8	Magnetic properties	1049
28.8.1	Ferromagnetism	1052
28.8.2	Antiferromagnetism and ferrimagnetism	1054
28.9	Dielectric properties	1055
28.9.1	Para-electric materials	1059
28.9.2	Ferroelectrics	1059
28.10	Optical properties of crystals	1060
28.10.1	Excitons and their properties	1061
28.10.2	Photoconductivity	1062
28.10.3	Luminescence	1063
28.10.4	Optoelectronic properties	1063
	Formula symbols used in quantum physics	1065
29	Tables in quantum physics	1071
29.1	Ionization potentials	1071
29.2	Atomic and ionic radii of elements	1078
29.3	Electron emission	1082
29.4	X-rays	1086
29.5	Nuclear reactions	1087
29.6	Interaction of radiation with matter	1088

29.7	Hall effect	1089
29.8	Superconductors	1091
29.9	Semiconductors	1093
29.9.1	Thermal, magnetic and electric properties of semiconductors .	1093

Part VI Appendix 1095

30 Measurements and measurement errors 1097

30.1	Description of measurements	1097
30.1.1	Quantities and SI units	1097
30.2	Error theory and statistics	1100
30.2.1	Types of errors	1100
30.2.2	Mean values of runs	1102
30.2.3	Variance	1104
30.2.4	Correlation	1105
30.2.5	Regression analysis	1106
30.2.6	Rate distributions	1106
30.2.7	Reliability	1111

31 Vector calculus 1115

31.1.1	Vectors	1115
31.1.2	Multiplication by a scalar	1116
31.1.3	Addition and subtraction of vectors	1117
31.1.4	Multiplication of vectors	1117

32 Differential and integral calculus 1121

32.1	Differential calculus	1121
32.1.1	Differentiation rules	1121
32.2	Integral calculus	1122
32.2.1	Integration rules	1123
32.3	Derivatives and integrals of elementary functions	1124

33 Tables on the SI 1125

Index 1131

With contributions by:

Blaze Babovsky, Technische Hochschule Mittelhessen
 Heiner Hahn, Physikalische Fakultät, Universität Frankfurt
 André Jahn, Universität Frankfurt
 Karl-Heinz Kampert, Universität Karlsruhe
 Wolf Sander Kries, Fachhochschule der Pfalz, Kaiserslautern
 Ina Krüger-Wiedorn, Naturwissenschaftliche Fakultät, Universität Tübingen
 Christa Lenz, Universität Frankfurt
 Monika Lutz, Fachhochschule Gießen-Erfurt
 Raffaele Mantiello, Universität Frankfurt
 Jörg Müller, University of Tennessee, Knoxville
 Jürgen Müller, Deutscher Verband für APD-Technologie, Fraunhofer
 Gottfried Mützelberg, Universität Gießen und GSI Darmstadt