

Contents

1	Photon Scattering – Form Factors	1
1.1	Compton Effect	1
1.2	Thomson Scattering	3
1.2.1	Classical Derivation	3
1.2.2	Quantum Mechanical Derivation	5
1.2.3	Quantum Mechanical Interpretation of r_e	6
1.3	Form Factor	7
1.3.1	Geometrical Interpretation of the Form Factor	7
1.3.2	Dynamical Interpretation of the Form Factor	10
1.4	Recoilless Scattering Off Crystals	10
1.5	Photon Scattering Off Free Electrons	11
	Literature	13
2	Lepton Scattering – Nucleon Radius	15
2.1	Electron-Quark Scattering	15
2.1.1	Mott Scattering	16
2.1.2	Inclusion of Quark Spin	19
2.2	Electron-Nucleon Scattering	20
2.2.1	Nucleon Radius	20
2.2.2	Nucleon Form Factor	21
2.3	Neutrino-Electron Scattering	22
2.4	Neutrino-Quark Scattering	23
2.4.1	Weak Potential	24
	Literature	24
3	Quasi-elastic Scattering – Virtual Photons and Gluons	25
3.1	Virtual Weizsäcker–Williams Photons	26
3.2	Virtual Bjorken–Feynman Partons – Deep Inelastic Scattering	28
3.2.1	Electron Scattering Off Quarks	29

3.2.2	Neutrino Scattering Off Quarks	31
3.2.3	Gluon Bremsstrahlung	33
3.3	Coupling Constants	36
3.3.1	Electromagnetic Coupling Constant α	36
3.3.2	Strong Coupling Constant α_s	38
3.3.3	Weak Coupling Constant α_W	39
	Literature	39
4	The Hydrogen Atom – The Playground of Quantum Mechanics	41
4.1	Level Diagram	41
4.1.1	Semiclassical.	41
4.1.2	Dirac Level Diagram	43
4.1.3	Zitterbewegung	45
4.1.4	Spin-Orbit Splitting.	46
4.2	Lamb Shift	47
4.2.1	Zero-Point Oscillation.	48
4.3	Hyperfine Structure	50
4.4	Hydrogen-Like Atoms	51
4.4.1	Muonic Atoms	51
	Literature	53
5	Many Electron Atoms – Shell Structure	55
5.1	Binding Energies	55
5.1.1	The Helium Atom.	55
5.1.2	Correlations	56
5.1.3	The Negative H^- Ion	57
5.1.4	The 2s, 2p Shells	57
5.2	Atomic Radii	59
5.2.1	Hydrogen and Helium.	59
5.2.2	Thomas–Fermi Model.	60
5.2.3	Alternative Definitions	62
5.3	Atoms with Magnetic Moment.	63
5.4	Ferromagnetism and Antiferromagnetism.	64
	Literature	65
6	Covalent and Ionic Binding – Electron Sharing	67
6.1	The Covalent Bond	67
6.1.1	The Hydrogen Molecule – A Case of Broken Symmetry	68
6.1.2	An Analogy	70
6.1.3	Covalent Bond in the (2s, 2p) Shells	71
6.1.4	Carbon - The Magic Atom	71
6.1.5	Energy Source Oxygen.	73

6.2	Ionic Bonds	74
	Literature	75
7	Intermolecular Forces – Building Complex Structures	77
7.1	Van der Waals Interaction	77
7.1.1	Van der Waals Interaction Between an Atom and a Conducting Wall	78
7.1.2	Van der Waals Interaction Between Two Atoms	78
7.1.3	Van der Waals Interaction and the Casimir Effect	79
7.1.4	Wall–Wall Interaction	80
7.2	Hydrogen Bridge Bond	82
7.2.1	Water	82
7.2.2	Water Molecule	83
7.2.3	Model of the Hydrogen Bridge Bond	83
7.2.4	Ice	84
7.2.5	Specific Heat	84
7.3	Hydrogen Bridge Bond in Biology	85
7.3.1	Primary Structures	85
7.3.2	Secondary Structure	85
7.3.3	α Helix	87
7.3.4	β -Pleated Sheet	87
7.3.5	Tertiary Structure and Higher Levels	88
	Literature	88
8	Cold Neutron – Spectroscopy of the Solid State	89
8.1	Dispersion Relations for Crystals	91
8.1.1	Sodium Crystal	92
8.1.2	Potassium Bromide Crystal	92
8.2	Localised Vibrational Mode	93
8.3	Dispersion Relations for Amorphous Substances	96
8.4	Specific Heat	97
8.4.1	Crystalline Substances	97
8.4.2	Amorphous Substances	98
	Literature	99
9	Quantum Gases – Quantum Degeneration	101
9.1	Fermi Gas	102
9.1.1	Fermi Energy, Fermi Momentum, Fermi Temperature	103
9.1.2	Transition to a Degenerate Fermi Gas	103
9.2	Bosonic Gas	104
9.2.1	Bose–Einstein Condensation	104
9.3	Coherent Photon Gas – Laser	107
	Literature	109

10 Quantum Liquids – Superfluidity	111
10.1 Normal Liquid ^3He	111
10.2 Superfluid ^4He	113
10.3 Superfluid Helium Droplets	116
10.4 Superfluid ^3He	116
Literature	117
11 Metals – Quasi-free Electrons	119
11.1 Metallic Bond	119
11.1.1 Metallic Hydrogen	119
11.1.2 Normal Metals	121
11.2 Electrical Conductivity	123
11.3 Cooper Pairs	123
11.4 Diamagnetism in Superconductors	126
11.5 Macroscopic Quantum Interference	128
11.6 Thermal Conductivity	130
Literature	132
12 Hadrons – Atoms of Strong Interaction	133
12.1 Quarkonia	133
12.2 Hadrons from Light Quarks	135
12.2.1 Nonrelativistic Quark Model	135
12.3 Chiral Symmetry Breaking	137
12.3.1 Constituent Quark	139
12.3.2 The Pion	142
12.3.3 Generalisation to $m_0 > 0$ and Two Quark Flavours	143
12.3.4 The Pion as a Collective State	144
Literature	147
13 The Nuclear Force – Pion Sharing	149
13.1 Repulsion at Short Distances	150
13.2 Attraction	150
13.3 Information from Light and Heavier Nuclei	151
Literature	153
14 Nuclei – Droplets of a Fermi Liquid	155
14.1 Global Properties – The Fermi-Gas Model	156
14.2 Individual Properties – Shell Model	157
14.3 Collective Excitations	159
14.3.1 Vibrational States	159
14.3.2 Model	159
14.3.3 Deformation and Rotational States	163
14.3.4 Deformation Versus Cooper Pairs	163
Literature	165

15 Stars, Planets, and Asteroids	167
15.1 The Sun and Sun-Like Stars	167
15.1.1 Equation of State	168
15.1.2 Virial Theorem	169
15.1.3 Size and Temperature	169
15.1.4 Proton Energy	170
15.1.5 Electron Energy	170
15.1.6 White Dwarfs	171
15.1.7 Brown Dwarfs	172
15.2 Energy Production in the Sun	172
15.2.1 Proton–Proton Cycle	173
15.2.2 $3\alpha \rightarrow {}^{12}\text{C}$ -Process	177
15.3 Stars More Massive than the Sun	179
15.3.1 Neutron Stars	180
15.3.2 Black Holes	180
15.3.3 Element Abundance	181
15.4 Planets and Asteroids	182
Literature	184
16 Elementary Particles – Fundamental Interactions	185
16.1 Families of Particles	185
16.1.1 W^\pm Boson Decays	186
16.1.2 Parity Violation and Weak Isospin	188
16.1.3 $K^0-\bar{K}^0$, $B^0-\bar{B}^0$ Oscillations and CP Violation	189
16.1.4 Neutrino Oscillations	191
16.2 Weak Quark Decays	194
16.2.1 Top Quark Decay	195
16.3 Z^0 and the Photon	196
16.4 Higgs Ex Machina	198
16.5 Proton Decay	202
Literature	205
17 Cosmology – The Early Universe	207
17.1 The Three Pillars of the Big Bang Model	208
17.1.1 The Expanding Universe	208
17.1.2 Cosmic Microwave Background Radiation	211
17.1.3 Primordial Abundance of the Elements	213
17.2 Some Problems with the Big Bang Model	214
17.2.1 Particle–Antiparticle Asymmetry	215
17.2.2 Dark Matter	216
17.2.3 Physics at the Planck Scale	217
Literature	218
Physical Constants	219
Index	221

Scattering and Structures

Essentials and Analogies in Quantum Physics

Povh, B.; Rosina, M.

2017, XVII, 227 p. 119 illus., Hardcover

ISBN: 978-3-662-54513-3