

Contents

1. Colored Centers in Ionic Crystals	1
1.1 The Mollwo–Ivey Law	2
1.2 The Jahn–Teller Effect	3
1.3 The Stokes Shift	4
1.4 Solutions	5
Further Comments on F-Centers	10
2. Unstable Diatomic Molecule	11
2.1 Preliminaries	11
2.2 A Molecule Which Is Only Stable in Its Excited State	12
2.3 Solutions	13
3. Neutrino Oscillations	17
3.1 Neutrino Masses and the Associated Oscillations	17
3.2 Solutions	18
4. Colored Molecular Ions	21
4.1 Carbohydrate Ions	21
4.2 Nitrogenous Ions	22
4.3 Solutions	23
5. Schrödinger’s Cat	27
5.1 The Quasi-Classical States of a Harmonic Oscillator	27
5.2 Construction of a Schrödinger-Cat State	28
5.3 Quantum Superposition Versus Statistical Mixture	29
5.4 The Fragility of a Quantum Superposition	30
5.5 Solutions	32
Conclusion	37
6. Direct Observation of Field Quantization	39
6.1 Quantization of a Mode of the Electromagnetic Field	39
6.2 The Coupling of the Field with an Atom	41
6.3 Interaction of the Atom and an “Empty” Cavity	42

6.4	Interaction of an Atom with a Quasi-Classical State	43
6.5	Large Numbers of Photons: Damping and Revivals	44
6.6	Solutions	45
	Reference	52
7.	Decay of a Tritium Atom	53
7.1	The Energy Balance in Tritium Decay	53
7.2	Solutions	54
8.	The Hydrogen Atom in Crossed Fields	57
8.1	The Hydrogen Atom in Crossed Electric and Magnetic Fields	57
8.2	Pauli's Result	58
8.3	Solutions	59
9.	Exact Results for the Three-Body Problem	61
9.1	The Two-Body Problem	61
9.2	The Variational Method	61
9.3	Relating the Three-Body and Two-Body Sectors.....	62
9.4	The Three-Body Harmonic Oscillator	63
9.5	From Mesons to Baryons in the Quark Model	63
9.6	Solutions	64
	References	68
10.	Analysis of a Stern–Gerlach Experiment	69
10.1	Preparation of the Neutron Beam	69
10.2	Spin State of the Neutrons.....	71
10.3	The Stern–Gerlach Experiment	71
10.4	Solutions	73
11.	Measuring the Electron Magnetic Moment Anomaly.....	79
11.1	Spin and Momentum Precession of an Electron in a Magnetic Field	79
11.2	Solutions	80
12.	Neutron Interferometry	83
12.1	Neutron Interferences	84
12.2	The Gravitational Effect	85
12.3	Rotating a Spin 1/2 by 360 Degrees.....	86
12.4	Solutions	88
	References	91

13. The Penning Trap	93
13.1 Motion of an Electron in a Penning Trap	93
13.2 The Transverse Motion	94
13.3 Measurement of the Electron Anomalous Magnetic Moment ..	95
13.4 Solutions	95
Reference	98
14. Quantum Cryptography	99
14.1 Preliminaries	99
14.2 Correlated Pairs of Spins	100
14.3 The Quantum Cryptography Procedure	102
14.4 Solutions	104
15. Hidden Variables and Bell's Inequalities	109
15.1 The Electron Spin	109
15.2 Correlations Between the Two Spins	109
15.3 Correlations in the Singlet State	110
15.4 A Simple Hidden Variable Model	111
15.5 Bell's Theorem and Experimental Results	112
15.6 Solutions	113
References	118
16. Hyperfine Structure in Electron Spin Resonance	119
16.1 Hyperfine Interaction with One Nucleus	120
16.2 Hyperfine Structure with Several Nuclei	120
16.3 Experimental Results	121
16.4 Solutions	123
17. The Spectrum of Positronium	127
17.1 Positronium Orbital States	127
17.2 Hyperfine Splitting	127
17.3 Zeeman Effect in the Ground State	128
17.4 Decay of Positronium	129
17.5 Solutions	131
References	134
18. Magnetic Excitons	135
18.1 The Molecule CsFeBr ₃	135
18.2 Spin-Spin Interactions in a Chain of Molecules	136
18.3 Energy Levels of the Chain	136
18.4 Vibrations of the Chain: Excitons	138
18.5 Solutions	140
Reference	145

19. Probing Matter with Positive Muons	147
19.1 Muonium in Vacuum	148
19.2 Muonium in Silicon	149
19.3 Solutions	151
20. Spectroscopic Measurement on a Neutron Beam	157
20.1 Ramsey Fringes	157
20.2 Solutions	159
Reference	163
21. The Quantum Eraser	165
21.1 Magnetic Resonance	165
21.2 Ramsey Fringes	166
21.3 Detection of the Neutron Spin State	168
21.4 A Quantum Eraser	169
21.5 Solutions	170
22. Molecular Lasers	179
22.1 Preliminaries	179
22.2 Molecular Lasers	180
22.3 Solutions	182
23. Energy Loss by Ions in Matter	187
23.1 Energy Absorbed by One Atom	188
23.2 Energy Loss in Matter	188
23.3 Solutions	190
24. Properties of a Bose–Einstein Condensate	195
24.1 Particle in a Harmonic Trap	195
24.2 Interactions Between Two Confined Particles	196
24.3 Energy of a Bose–Einstein Condensate	197
24.4 Condensates with Repulsive Interactions	197
24.5 Condensates with Attractive Interactions	198
24.6 Solutions	199
Further Comments	204
25. Quantum Reflection of Atoms from a Surface	205
25.1 The Hydrogen Atom–Liquid Helium Interaction	205
25.2 Excitations on the Surface of Liquid Helium	207
25.3 Quantum Interaction Between H and Liquid He	208
25.4 The Sticking Probability	208
25.5 Solutions	209
References	215

26. Laser Cooling and Trapping 217

 26.1 Optical Bloch Equations for an Atom at Rest 217

 26.2 The Radiation Pressure Force 218

 26.3 Doppler Cooling 219

 26.4 The Dipole Force 220

 26.5 Solutions 220

27. Quantum Motion in a Periodic Potential 227

 27.1 Band Structure in a Periodic Potential 227

 27.2 Bloch Oscillations 228

 27.3 Solutions 230

Author Index 239

Subject Index 241