

Contents

Part I Prerequisites

1	A Short Introduction to Laser Physics	3
1.1	The Einstein Coefficients	3
1.2	Fundamentals of the Laser	6
1.2.1	Elementary Laser Theory	6
1.2.2	Realization of the Laser Principle	8
1.3	Pulsed Lasers	10
1.3.1	Frequency Comb	10
1.3.2	Carrier Envelope Phase	12
1.3.3	Husimi Representation of Laser Pulses	14
1.A	Some Gaussian Integrals	15
	References	16
2	Time-Dependent Quantum Theory	17
2.1	The Time-Dependent Schrödinger Equation	17
2.1.1	Introduction	18
2.1.2	Time-Evolution Operator	20
2.1.3	Spectral Information	23
2.1.4	Analytical Solutions for Wavepackets	25
2.2	Analytical Approaches	30
2.2.1	Feynman's Path Integral	30
2.2.2	Semiclassical Approximation	35
2.2.3	Time-Dependent Perturbation Theory	38
2.2.4	Magnus Expansion	40
2.2.5	Time-Dependent Hartree Method	42
2.2.6	Quantum-Classical Methods	43
2.2.7	Floquet Theory	45
2.3	Numerical Methods	48
2.3.1	Orthogonal Basis Expansion	48
2.3.2	Split-Operator FFT Method	52

2.3.3	Alternative Methods of Time-Evolution	56
2.3.4	Semiclassical Initial Value Representations	58
2.A	The Royal Road to the Path Integral	65
2.B	Variational Calculus	67
2.C	Stability Matrix	69
2.D	From the HK- to the VVG-Propagator	71
References		72

Part II Applications

3	Field Matter Coupling and Two-Level Systems	77
3.1	Light Matter Interaction	77
3.1.1	Minimal Coupling	77
3.1.2	Length Gauge	79
3.1.3	Kramers–Henneberger Transformation	81
3.1.4	Volkov Wavepacket	82
3.2	Analytically Solvable Two-Level Problems	83
3.2.1	Dipole Matrix Element	83
3.2.2	Rabi Oscillations Induced by a Constant Perturbation ..	84
3.2.3	Time-Dependent Perturbations	86
3.2.4	Exactly Solvable Time-Dependent Cases	89
3.A	Generalized Parity Transformation	91
3.B	Two-Level System in an Incoherent Field	93
References		95
4	Single Electron Atoms in Strong Laser Fields	97
4.1	The Hydrogen Atom	97
4.1.1	Hydrogen in Three Dimensions	98
4.1.2	The One-Dimensional Coulomb Problem	99
4.2	Field Induced Ionization	101
4.2.1	Tunnel Ionization	101
4.2.2	Multiphoton Ionization	104
4.2.3	ATI in the Coulomb Potential	109
4.2.4	Stabilization in Very Strong Fields	111
4.2.5	Atoms Driven by HCP	113
4.3	High Harmonic Generation	119
4.3.1	Three-Step Model	119
4.3.2	Odd Harmonics Rule	123
4.3.3	Semiclassical Explanation of the Plateau	124
4.3.4	Cutoff and Odd Harmonics Revisited	126
4.A	More on Atomic Units	131
References		133

5	Molecules in Strong Laser Fields	135
5.1	The Molecular Ion H_2^+	135
5.1.1	Electronic Potential Energy Surfaces	135
5.1.2	The Morse Potential	140
5.2	H_2^+ in a Laser Field	142
5.2.1	Frozen Nuclei	142
5.2.2	Nuclei in Motion	147
5.3	Adiabatic and Nonadiabatic Nuclear Dynamics	151
5.3.1	Born-Oppenheimer Approximation	152
5.3.2	Dissociation in a Morse Potential	156
5.3.3	Coupled Potential Surfaces	159
5.3.4	Femtosecond Spectroscopy	168
5.4	Control of Molecular Dynamics	177
5.4.1	Control of Tunneling	178
5.4.2	Control of Population Transfer	185
5.4.3	Optimal Control Theory	189
5.4.4	Genetic Algorithms	195
5.4.5	Toward Quantum Computing with Molecules	197
5.A	Relative and Center of Mass Coordinates for H_2^+	200
5.B	Perturbation Theory for Two Coupled Surfaces	201
5.C	Reflection Principle of Photodissociation	202
5.D	The Undriven Double Well Problem	203
5.E	The Quantum Mechanical Adiabatic Theorem	205
	References	206
	Index	209