Contents

1 Analogy Between Quantum Mechanics and Optics 1
1.1 Wave Equation 2
1.1.1 One-Dimensional Scalar Wave Equation 2
1.1.2 One-Dimensional Stationary Schrödinger Equation 4
1.2 Optical Waveguide and Quantum Well 5
1.2.1 Asymmetric Optical Waveguide 6
1.2.2 Asymmetric Square Potential Well 7
1.3 Tunneling Effect 8
1.3.1 Optical Energy Coupling Structure 9
1.3.2 Barrier Tunneling 10
1.4 Square-Law Distribution 12
1.4.1 Optical Waveguide with Square-Law-Distributed Refractive Index 12
1.4.2 Harmonic Oscillator 13
References 14

2 Analytical Transfer Matrix Method 15
2.1 Basic Characteristics of the Transfer Matrix 16
2.1.1 Establish a Transfer Matrix 16
2.1.2 Basic Characteristics of the Transfer Matrix 19
2.2 Solving Simple One-Dimensional Problems 24
2.2.1 Asymmetric Rectangular Potential Well 24
2.2.2 Tunneling Coefficient of Rectangular Barrier 25
References 25

3 Semiclassical Approximation 27
3.1 WKB Wave Function 28
3.2 Semiclassical Limit 33
3.3 Connection Formulas at Turning Points 34

Bibliografische Informationen
http://d-nb.info/1038373166

digitalisiert durch DEUTSCHE NATIONAL BIBLIOTHEK

3.4 Application of the WKB Approximation 37
3.4.1 Bound State in a Potential Well 37
3.4.2 Barrier Tunneling 39
3.4.3 Some Related Topics 41
References 44

4 Exact Quantization Condition via Analytical Transfer Matrix Method 47
4.1 Double-Well Potentials 48
4.2 One-Dimensional Potential of Arbitrary Shape 51
4.2.1 Analysis of One-Dimensional Problems via Transfer Matrix 51
4.2.2 Phase Shift at Classical Turning Points 56
4.2.3 Phase Contribution of Scattered Subwaves 57
4.2.4 Eigenvalue Equation 58
4.2.5 The Calculation of the Wave Function 60
4.2.6 Accidental Event of the WKB Approximation 61
4.3 Energy Splitting in Symmetric Double-Well Potentials 62
4.3.1 One-Dimensional Square Double-Well Potential 62
4.3.2 One-Dimensional Symmetric Double-Well Potentials 64
4.4 Example of the Lennard-Jones Potential 66
4.5 Direct Derivation of the Exact Quantization Condition 69
References 72

5 Barrier Tunneling 75
5.1 One-Dimensional Arbitrary Continuous Barrier 76
5.1.1 ATM Reflection Coefficient with a Constant Effective Mass 76
5.1.2 The Case of $m = 1$ and $m = 2$ 81
5.1.3 Continuous Potential at the Reference Point 83
5.2 Compared with WKB Approximation 84
5.2.1 Barrier with Adjacent Wells 84
5.2.2 Band-Pass Filter Based on a Gaussian-Modulated Superlattice 86
5.3 One-Dimensional Arbitrary Continuous Barrier with Position-Dependent Effective Mass 88
5.3.1 Derivation of Reflection Coefficient 88
5.3.2 The Semiconductor Single Barrier Structure 93
5.3.3 Semiconductor Double-Barrier Structure with Nonlinear Potential 94
References 95

6 The Scattered Subwaves 97
6.1 Basic Concept 98
6.1.1 Conceptual Difference of the Wave Vector 98
6.1.2 Numerical Comparison of the Total Wavenumber and the Main Wavenumber 99
6.2 The Scattered Subwaves and the Quantum Reflection 100
6.2.1 Research Progress in Quantum Reflection 101
6.2.2 Explanation by the ATM Method 102
6.3 Time Issue in One-Dimensional Scattering 109
6.3.1 Barrier Tunneling Time and the Hartman Effect 109
6.3.2 Analogy Between Electron Tunneling and Electromagnetic Tunneling 112
6.3.3 Reinterpretation of the Phase Time 114
6.3.4 Generalized Expression for Reflection Time 116
6.3.5 General Transmission Time 122
6.3.6 Scattered Subwaves and the Hartman Effect 126
6.4 Scattered Subwaves and the Supersymmetric Quantum Mechanics 129
6.4.1 Brief Introduction of Supersymmetric Quantum Mechanics 130
6.4.2 SWKB Approximation 132
6.4.3 Consideration of the Scattered Subwaves 134
6.4.4 Why Is SWKB Quantization Condition Exact? 141
References 144