

Contents

1	Introduction	1
2	Analogies Between Ballistic Electrons and Electromagnetic Waves	9
2.1	Analog Parameters for Ballistic Electrons and Classical Electromagnetic Waves	10
2.2	Geometrical Electron Optics	14
2.2.1	Electron Prism	15
2.2.2	Electron Lens	17
2.2.3	Magnetic Electron/Hole Focusing	18
2.2.4	Electron Beam Splitter	21
2.3	Quantum/Electromagnetic Waveguides	22
2.3.1	Dispersion Equation	23
2.3.2	Coupled Electron Waveguides	25
2.4	Analogous Quantum/Electromagnetic Filters	27
2.5	Analogous Quantum/Electromagnetic Tunneling Structures	29
2.5.1	Quantum/Electromagnetic Resonant Tunneling Wells	30
2.5.2	Quantum/Electromagnetic Resonant Tunneling Wires	32
2.5.3	Quantum/Electromagnetic Resonant Tunneling Dots	33
2.6	Photonic Band Crystals	36
2.7	Photonic Bloch Oscillations	40
2.8	Electron Diffraction	44
2.9	Electron Interference	47
2.10	Analog Quantum/Electromagnetic Devices with Non-Uniform Cross-Section	50
2.10.1	Analog Quantum/Electromagnetic T-Shaped Devices	51
2.10.2	Analog Quantum/Electromagnetic Dots with Non-Uniform Cross-Section	54
2.11	Quantum/Electromagnetic Cavities	56
2.12	Electromagnetic Analogs of Type II Semiconductor Heterostructures	58

3	Electron/Electromagnetic Multiple Scattering and Localization	63
3.1	Quantum/Electromagnetic Wave Propagation in Disordered Media	64
3.1.1	Microscopic Theory of Transport	65
3.1.2	Single-Scattering Matrix	67
3.1.3	Velocities of Electromagnetic Waves in Random Media	68
3.1.4	Length Scales	72
3.2	Light Conductance	73
3.3	Photonic Hall and Magnetoresistance Effects	76
3.4	Interference Effects in Multiple Scattering	79
3.4.1	Universal Conductance Fluctuations	79
3.4.2	Light Intensity Correlations	81
3.4.3	Weak Localization	88
3.5	Localization Criteria	93
3.5.1	Ioffe–Regel Criterion for Localization	94
3.5.2	Thouless Criterion for Localization	95
3.5.3	Vanishing of Transport Mean Free Path as Localization Criterion	98
3.6	Experimental Evidence of Light Localization	98
4	Acoustic Analogies for Quantum Mechanics	103
4.1	Acoustic Bloch Waves	103
4.2	Acoustic Analogs of Quasicrystals	105
4.3	Multiple Scattering and Localization of Acoustic Waves	106
4.4	Acoustic Wave Propagation in Nonlinear Disordered Systems	112
4.5	Acoustical Analog of Persistent Currents in Mesoscopic Normal Metal Rings	115
4.6	Acoustic Casimir Effect	116
5	Optical Analogs for Multilevel Quantum Systems	119
5.1	Optical Analog for a Two-Level Quantum System	119
5.2	Dynamical Behavior of the Two-Level Optical Atom	124
5.2.1	Adiabatic Regime	125
5.2.2	Rabi Oscillations	125
5.2.3	Multiphoton Transitions and Bloch–Siegert Shifts	127
5.2.4	Zener-Tunneling Regime	128
5.3	Macroscopic Optical Band Structure	129
5.4	Comparison with Spin-Resonant Phenomena	132
5.5	Limitations of the Optical Analog of a Quantum Two-Level System	135
5.6	Three- and Four-Level Optical Atoms	136
5.7	Nonlinear Optical Atoms	137

5.8	Spectral Focusing in Two-Photon Processes	138
5.9	Spectral Fresnel Lens	141
6	Particle Optics	143
6.1	Particle Optics Versus Classical Optics	145
6.2	Atom Interactions with Light	147
6.3	Geometrical Particle Optics	150
6.3.1	Collimation	153
6.3.2	Focusing	154
6.3.3	Mirrors	159
6.3.4	Atom Channeling	162
6.3.5	Beam Splitters	163
6.4	Particle Wave Optics	165
6.4.1	Diffraction	166
6.4.2	Interference	170
6.4.3	Holography	175
6.5	Atom Waveguides	177
6.5.1	Atom Coupler	180
6.5.2	Bloch Oscillations in Atom Optics	181
6.5.3	Atomic Wavepackets	182
6.5.4	Atom Lenses and Mirrors in the Time Domain	182
6.6	Quasiparticle Optics	184
7	Quantum/Classical Nonlinear Phenomena	187
7.1	Nonlinear Phenomena in Resonant Tunneling Diodes	187
7.2	Nonlinear Barrier Traversal	191
7.3	Classical Nonlinear Analogs of Bose–Einstein Condensates	191
7.3.1	Four-Wave Mixing in the BEC	194
7.3.2	BEC Solitons	195
7.3.3	BEC Holography	201
7.4	BECs and Gravitation	203
7.5	Nonlinear Atom Optics	206
7.6	Classical Analog of Andreev Reflection	208
8	Quantum/Classical Phase Space Analogies	211
8.1	Classical/Quantum Hamiltonian Formulation	212
8.2	Quantum/Classical Systems with Identical Motion	217
8.3	Operator Formalism in Classical Physics	221
8.3.1	Differential Operators in Classical Optics	221
8.3.2	Integral Operators in Classical Optics	225
8.3.3	Operator Factorization	226
8.4	Quantum/Classical Chaos	227
8.5	Quantum/Classical Uncertainty Relations	229
8.6	Quantum/Classical Phase Space Distribution Functions	232
8.7	Quantum/Classical Interference in Phase Space	236

8.8	Quantum/Classical Transitions	240
8.9	Quantum/Classical Transformations	242
9	Analogies Between Quantum and Classical Computing . . .	247
9.1	Bits and Registers	249
9.2	Logical Operations	256
9.3	Computing Algorithms	261
9.4	Entangled States	270
9.5	Teleportation	276
10	Other Quantum/Classical Analogies	279
10.1	Transmission Line Analogy to Ballistic Electron Motion . . .	279
10.2	Quantum Analog of the Electro-Optic Modulator	280
10.3	Electronic Flute	282
10.4	Quantum Anyon/Classical Vortex Analogy	283
10.5	Mechanical Model of Rotational States in Even–Even Nuclei	285
10.6	Quantum/Classical Malus Law	287
10.7	Analogies Between the Wave Equation and the Time-Independent Schrödinger Equation	288
	10.7.1 Classical Analogs of Quantum Fock States	288
	10.7.2 Nonlinear Quantum/Classical Operators	290
	10.7.3 Optical Corrals	291
10.8	Analogies Between the Wave Equation and the Time-Independent Dirac Equation	291
10.9	Analogies Between the Wave Equation and the Time-Dependent Schrödinger Equation	293
	10.9.1 Fractional Quantum Revivals and the Fractional Optical Talbot Effect	296
	10.9.2 Non-Paraxial Case	298
10.10	Maxwell Equations in Spinor Form	299
10.11	Diffraction in Time	300
10.12	Quantum/Classical Tunneling	304
	10.12.1 Setups for Direct Measurement of the Quantum/Classical Tunneling Time	308
	10.12.2 Quantum/Classical Larmor Clocks	311
10.13	Classical Analogs of the Aharonov–Bohm Effect	314
	References	319
	Index	341