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Quantum Transport and Dissipation

Preface

In recent years, systems intermediate between macroscopic and microscopic scales, where quantum coherence becomes important, have developed into a main area of research in modern condensed-matter physics. The notion of “mesoscopic systems” has been coined to characterize this field. One of its fascinating aspects is that it connects quite different subjects ranging from quantum transport theory to quantum chaos. Here, technical applications, for instance single-electron transistors, are closely tied to fundamental questions in quantum and statistical mechanics. As a result of the rapid growth of the literature, it has become very difficult for young scientists to obtain an overview of the foundations of this interdisciplinary field.

The aim of this book is to provide an introduction into some of the theoretical aspects. At the same time, we intend to guide towards the forefront of ongoing research in an immensely vivid subject. This goal is almost impossible to achieve. We can only hope that the compromise attempted here will prove successful.

In order to cover the wide range of topics, the book has been written by several authors. Each of the six chapters is aimed at a reasonably self-contained introduction into the principal issues of a particular subfield, which we believe to be representative. The first chapter deals with the basic notions in quantum transport theory, including weak localization, universal conductance fluctuations and the Landauer-Büttiker scattering formalism. It also provides some background for diagrammatic techniques in weakly disordered systems. The second chapter introduces the theory of the quantum Hall effect, both integer and fractional. The concept of localization as well as Laughlin’s theory of the effect of interactions in the fractional case are treated here on an elementary level. Quantization of conductance in quantum wires, including the effects of impurity scattering and interactions, is outlined here. The subject of the following chapter are single-electron tunneling and Coulomb-blockade phenomena for metallic and superconducting junction devices. Beyond the standard rate equation, it contains a discussion of the effect of the electromagnetic environment and of nonperturbative effects.

In chapter four, concepts for the description of dissipation in quantum systems, in particular the role of the coupling to a heat bath, are explained. This chapter also includes the Feynman path-integral formulation via influence functionals and applies this formalism to dissipative tunneling. The fifth chapter is devoted to the theory of strongly driven quantum systems. On basis of the general Floquet theory, archetypal problems like driven tunneling—together with its dynamical destruction—in a driven double well and the control of a quantum dynamics via a sequence of coherent laser pulses are discussed there. Quantum chaos and its relation to transport phenomena are treated in the final chapter. The main topics are semiclassical methods, the interplay of chaos with tunneling and localization, and quantum chaos in scattering and dissipative systems.

The present volume introduces many of the basic ideas and techniques in this field which are necessary to master the more specialized original literature. As such it is mainly addressed to those who intend to start research in this very active area. It

should also be useful for physicists in other fields who would like to learn about this subject or to experimentalists for a better understanding of the crucial theoretical concepts. It is obvious that many more interesting topics like persistent currents and the physics of semiconductor quantum dots could not be included or could only be touched very briefly. Nevertheless, we are confident that the present volume reflects at least the cornerstones of the physics of mesoscopic systems and conveys the excitement in this area of research.

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Contents

1	Theory of Coherent Transport	1
1.1	Introduction	1
1.2	Scattering and Linear Response	7
1.2.1	Disorder, density of states and scattering	8
1.2.2	Green functions	15
1.2.3	Kubo-Greenwood formula	20
1.3	Weak Localization	24
1.3.1	Coherent Backscattering	24
1.3.2	Aharonov-Bohm interference effects	34
1.3.3	Dephasing	40
1.4	Universal Conductance Fluctuations	45
1.4.1	Self-averaging	45
1.4.2	Diagrammatic theory	47
1.4.3	Random matrix theory	54
1.5	The Landauer-Büttiker formalism	60
1.5.1	Landauer formula	61
1.5.2	Scattering theory of multiprobe conductances	64
1.5.3	Symmetry of electrical conduction	72
	References	74
2	Quantization of Transport	79
2.1	Noninteracting electrons in reduced dimensions	79
2.1.1	The Landau model	79
2.1.2	Confinement and magnetic field	82
2.1.3	Influence of impurities	88
2.1.4	Percolation limit and localization	94
2.2	The integer quantum Hall effect	100
2.2.1	Experiment	100
2.2.2	Electrical conductivity	102
2.2.3	Understanding the integer quantum Hall effect	105
2.3	Coulomb interaction and magnetic field	110
2.3.1	The fractional quantum Hall effect	110
2.3.2	Few electrons with Coulomb interaction	111
2.3.3	Fractional quantum Hall states	118
2.4	Conductance quantization	126
2.4.1	Experimental results	126
2.4.2	Conductance quantization in ideal quantum wires	127

2.4.3	Adiabatic constrictions	128
2.4.4	Disorder	132
2.4.5	Electron-phonon interaction	134
2.4.6	Electron-electron interaction	135
2.5	Conclusion	143
	References	143

3 Single-Electron Tunneling 149

3.1	Introduction	149
3.2	Charging energy and single-electron devices	151
3.2.1	The energy scale	152
3.2.2	Single-electron box	152
3.2.3	Single-electron transistor	154
3.3	Tunneling rates and I - V characteristics	156
3.3.1	The single-electron tunneling rate	156
3.3.2	Master equation for sequential tunneling	158
3.3.3	Cotunneling processes	161
3.3.4	Broadening of the steps	162
3.4	Influence of the electromagnetic environment	163
3.4.1	The model Hamiltonian	163
3.4.2	The single-electron tunneling rate	166
3.4.3	General properties	167
3.4.4	The effect of an Ohmic resistor	169
3.4.5	Other environments	171
3.5	Charging effects and superconductivity	172
3.5.1	Charging effects on quasiparticle tunneling	173
3.5.2	Two-electron tunneling, Andreev reflection	174
3.5.3	Parity effects in small superconductors	176
3.5.4	I - V characteristics of NSN transistors	180
3.5.5	Coherent Cooper-pair tunneling	183
3.5.6	Andreev spectroscopy of Josephson tunneling	184
3.5.7	Incoherent Cooper-pair tunneling	188
3.6	Effective-action description	189
3.6.1	The effective action in imaginary times	189
3.6.2	Single-particle and Cooper-pair tunneling	190
3.6.3	Higher-order processes	192
3.6.4	Josephson current through SNS transistors	194
3.6.5	Proximity effect	196
3.7	Real-time evolution of the density matrix	198
3.7.1	Phase representation	199
3.7.2	Charge representation	200
3.7.3	Diagrams and rules	201

3.7.4	Simple examples, SET and cotunneling	203
3.7.5	Resonant tunneling	204
3.7.6	The current	206
3.7.7	Charge fluctuations in the single-electron box	207
3.7.8	Conductance oscillations in the SET transistor	208
3.8	Outlook	209
	References	210
4	Dissipative Quantum Systems	213
4.1	Introduction	213
4.2	Description of dissipation in quantum mechanics	214
4.2.1	Hamiltonian for system and heat bath	214
4.2.2	Elimination of the heat bath	215
4.2.3	Spectral density of bath modes	216
4.2.4	Rubin model	217
4.3	Density matrices	219
4.4	Linear damped systems	221
4.4.1	Response function	221
4.4.2	Fluctuation-dissipation theorem	224
4.4.3	Correlation functions of the damped harmonic oscillator	225
4.4.4	Free damped particle	228
4.5	Short introduction to path integrals	229
4.6	Dissipation within the path-integral formalism	232
4.6.1	Influence functional	232
4.6.2	Elimination of the heat bath	234
4.6.3	Evaluation of the fluctuations	237
4.6.4	Effective action	239
4.7	Decay of a metastable state	240
4.7.1	Crossover temperature	241
4.7.2	Imaginary part of the free energy	243
4.7.3	Above crossover	244
4.7.4	Zero temperature	245
	References	247
5	Driven Quantum Systems	249
5.1	Introduction	249
5.2	Time-dependent interactions	250
5.2.1	Laser interactions	250
5.2.2	Spin magnetic resonance	251
5.3	Floquet and generalized Floquet theory	252

5.3.1	Floquet theory	252
5.3.2	General properties of Floquet theory	254
5.3.3	Time-evolution operators for Floquet Hamiltonians	256
5.3.4	Generalized Floquet theory	258
5.3.5	The (t, t') -formalism	259
5.4	Exactly solvable driven quantum systems	261
5.4.1	Driven quantum oscillators	261
5.4.2	Periodically driven two-level systems	263
5.4.3	Quantum systems driven by circularly polarized fields	268
5.5	Numerical approaches to periodically driven quantum systems	270
5.5.1	Method of Floquet matrix	270
5.5.2	Matrix-continued-fraction method	271
5.6	Coherent tunneling in driven bistable systems	273
5.6.1	Limits of slow and fast driving	275
5.6.2	Driven tunneling near a resonance	276
5.6.3	Coherent destruction of tunneling	277
5.6.4	Two-state approximation to driven tunneling	280
5.7	Laser control of quantum dynamics	281
5.8	Conclusions and outlook	283
	References	284
6	Chaos, Coherence, and Dissipation	287
6.1	Introduction	287
6.2	Quasiclassical chaos	290
6.2.1	Time-domain aspects	290
6.2.2	Energy-domain aspects	303
6.3	Chaos and quantum coherence	317
6.3.1	Chaotic tunneling	317
6.3.2	Quantum chaos in extended systems	323
6.4	Quantum chaos in open systems	333
6.4.1	Chaotic scattering	333
6.4.2	Quantum chaos with dissipation	341
6.5	Conclusion	350
	References	352
	Author Index	359
	Subject Index	367

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