

Contents

Acknowledgements	i
Abstract	iii
1 Introduction	1
1.1 Historical Developments	1
1.2 Outline	4
2 Generalities	5
2.1 Fluctuation Theorem	5
2.2 Thermodynamic Entropy Production	6
2.3 Symmetry Relations for the Response Properties	7
2.4 Central Limit Theorem	8
2.5 Schnakenberg's Network Theory	8
2.6 Gillespie's Algorithm	9
2.7 A Simple Stochastic Process	10
3 Two Stochastic Models	13
3.1 Model With Constant Rates	13
3.1.1 Counting Statistics	13
3.1.2 Affinity Relations	15
3.1.3 Consequences of the Central Limit Theorem	16
3.1.4 Fluctuation Relation	17
3.1.5 Proof of Consistency for Systems Near Equilibrium	18
3.1.6 Response Properties	19
3.2 Model With Linear Rates	20
3.2.1 Master Equation	20
3.2.2 Graph Analysis and Affinities	20
3.2.3 Counting Statistics	21
3.2.4 Finite-Time Fluctuation Relation	23
3.2.5 Response Properties	26
4 Charge Transport in Conductive Channels	27
4.1 Conductive Channels	27
4.1.1 Stochastic Diffusion Equations	28
4.1.2 Mean-Field Equations Under Stationary Conditions	29
4.2 Numerical Simulation Method	29
4.2.1 Discretizing the Conductive Channel in Space	29
4.2.2 Master Equation	30

4.3	Graph Analysis and Affinity	31
4.4	The Current and Counting Statistics	31
4.5	Fluctuation Theorem for the Current	32
4.6	Finite-Time Fluctuation Relation in the Low-Density Limit	33
5	Charge Transport in p-n Junction Diodes	43
5.1	p - n Junction Diodes	43
5.1.1	Stochastic Diffusion-Reaction Equations	45
5.1.2	Mean-Field Equations Under Stationary Conditions	46
5.2	Numerical Simulation Method	47
5.2.1	Discretizing the p - n Junction Diode in Space	47
5.2.2	Master Equation	48
5.3	Density Profiles of Charge Carriers and Potential	50
5.4	The Current and Counting Statistics	50
5.5	Fluctuation Theorem for the Current	52
5.6	Current-Voltage Characteristics	55
6	Charge Transport in Bipolar n-p-n Junction Transistors	57
6.1	Bipolar n - p - n Junction Transistors	57
6.2	Numerical Simulation Method	59
6.2.1	Discretizing the Bipolar n - p - n Junction Transistor in Space	60
6.2.2	Master Equation	61
6.3	The Currents and Counting Statistics	62
6.4	Fluctuation Theorem for Currents	63
6.5	Response Properties	66
6.6	Current-Voltage Characteristics	68
7	Charge Transport in Tunnel Junctions	73
7.1	Tunnel Junctions	73
7.2	Master Equation	74
7.3	Counting Statistics	75
7.4	Fluctuation Theorem for the Current	76
7.5	Response Properties	78
7.6	Current-Voltage Characteristics	80
8	Conclusion and Perspectives	83
Appendix A	Intrinsic Energy Change in Electrostatic Systems	87
Appendix B	Stochastic Process of Langevin Type	93
Appendix C	The Continuum Limit	97
Appendix D	Variable Rescaling	99
Appendix E	Numerical Methods	101
Appendix F	Computer Programming	107
Bibliography		119