

## Contents

**Preface – Superconductivity and Little’s Phase Slips in Nanowires** *IX*

**Abbreviations – Short List** *XI*

**Notations – Short List** *XIII*

**Color Plates** *XV*

<b>1</b>	<b>Introduction</b>	<b>1</b>
<b>2</b>	<b>Selected Theoretical Topics Relevant to Superconducting Nanowires</b>	<b>15</b>
2.1	Free or Usable Energy of Superconducting Condensates	15
2.2	Helmholtz and Gibbs Free Energies	18
2.3	Fluctuation Probabilities	23
2.4	Work Performed by a Current Source on the Condensate in a Thin Wire	27
2.5	Helmholtz Energy of Superconducting Wires	29
2.6	Gibbs Energy of Superconducting Wires	31
2.7	Relationship between Gibbs and Helmholtz Energy Densities	35
2.8	Relationship between Thermal Fluctuations and Usable Energy	36
2.9	Calculus of Variations	38
2.10	Ginzburg–Landau Equations	39
2.11	Little–Parks Effect	46
2.12	Kinetic Inductance and the CPR of a Thin Wire	50
2.13	Drude Formula and the Density of States	51
<b>3</b>	<b>Stewart–McCumber Model</b>	<b>53</b>
3.1	Kinetic Inductance and the Amplitude of Small Oscillations	60
3.2	Mechanical Analogy for the Stewart–McCumber Model	62
3.2.1	Defining the Supercurrent Through Helmholtz Free Energy	65
3.2.2	Cubic Potential	66
3.2.3	Thermal Escape from the Cubic Potential	67
3.3	Macroscopic Quantum Phenomena in the Stewart–McCumber Model	68
3.3.1	MQT in a Cubic Potential at High Bias Currents	71

3.4	Schmid–Bulgadaev Quantum Phase Transition in Shunted Junctions	74
3.5	Stewart–McCumber Model with Normalized Variables	76
<b>4</b>	<b>Fabrication of Nanowires Using Molecular Templates</b>	<b>79</b>
4.1	Choice of Templating Molecules	86
4.2	DNA Molecules as Templates	86
4.3	Significance of the So-Called “White Spots”	88
<b>5</b>	<b>Experimental Methods</b>	<b>91</b>
5.1	Sample Installation	91
5.2	Electronic Transport Measurements	95
<b>6</b>	<b>Resistance of Nanowires Made of Superconducting Materials</b>	<b>101</b>
6.1	Basic Properties	101
6.2	Little’s Phase Slips	105
6.3	Little’s Fit	108
6.4	LAMH Model of Phase Slippage at Low Bias Currents	115
6.5	Comparing LAMH and Little’s Fit	122
<b>7</b>	<b>Golubev and Zaikin Theory of Thermally Activated Phase Slips</b>	<b>125</b>
<b>8</b>	<b>Stochastic Premature Switching and Kurkijärvi Theory</b>	<b>131</b>
8.1	Stochastic Switching Revealed by $V$ – $I$ Characteristics	131
8.2	“Geiger Counter” for Little’s Phase Slips	135
8.3	Measuring Switching Current Distributions	139
8.4	Kurkijärvi–Fulton–Dunkleberger (KFD) Transformation	143
8.5	Examples of Applying KFD Transformations	148
8.6	Inverse KFD Transformation	152
8.7	Universal $3/2$ Power Law for Phase Slip Barrier	153
8.8	Rate of Thermally Activated Phase Slips at High Currents	157
8.9	Kurkijärvi Dispersion Power Laws of $2/3$ and $1/3$	160
<b>9</b>	<b>Macroscopic Quantum Tunneling in Thin Wires</b>	<b>163</b>
9.1	Giordano Model of Quantum Phase Slips (QPS) in Thin Wires	165
9.2	Experimental Tests of the Giordano Model	175
9.3	Golubev and Zaikin QPS Theory	183
9.4	Khlebnikov Theory	185
9.5	Spheres of Influence of QPS and TAPS Regimes	187
9.6	Kurkijärvi–Garg Model	189
9.7	Theorem: Inverse Relationship between Dispersion and the Slope of the Switching Rate Curve	195
<b>10</b>	<b>Superconductor–Insulator Transition (SIT) in Thin and Short Wires</b>	<b>197</b>
10.1	Simple Model of SIT in Thin Wires	207

11	<b>Bardeen Formula for the Temperature Dependence of the Critical Current</b>	213
	<b>Appendix A Superconductivity in MoGe Alloys</b>	215
	<b>Appendix B Variance and the Variance Estimator</b>	217
	<b>Appendix C Problems and Solutions</b>	223
	<b>References</b>	241
	<b>Index</b>	247