

Contents

The authors' note — v

1	Phenomenological thermodynamics of irreversible processes — 1
1.1	Main postulates of non-equilibrium thermodynamics — 1
1.1.1	Thermodynamic description of equilibrium and non-equilibrium systems — 1
1.1.2	Local equilibrium principle — 3
1.1.3	Entropy balance equation and conservation laws — 4
1.1.4	Generalized flows and generalized thermodynamic forces — 7
1.1.5	Generalized transport coefficients and the Onsager symmetry relations — 9
1.1.6	Variational principles in linear non-equilibrium thermodynamics — 10
1.1.7	Minimum entropy production principle for weakly non-equilibrium steady states — 12
1.2	On the application of the Onsager theory — 13
1.2.1	Thermoelectric phenomena. The Peltier, Seebeck, Thomson effects and their relationship — 13
1.2.2	Effects in an external magnetic field — 19
1.3	Self-organization in highly non-equilibrium systems — 28
1.3.1	Non-equilibrium dissipative structures — 28
1.3.2	The Glansdorff–Prigogine universal evolution criterion — 29
1.3.3	Ways of describing strongly non-equilibrium systems — 31
1.3.4	Stability of states of highly non-equilibrium systems — 34
1.3.5	The Lyapunov global stability criterion — 36
1.3.6	Dynamical systems with one degree of freedom — 38
1.3.7	Dynamical systems with two degrees freedom — 39
1.3.8	Dynamic chaos — 45
1.3.9	Dynamic chaos in one-dimensional mappings — 51
	Problems to Chapter 1 — 57
2	Brownian Motion — 59
2.1	The Langevin equation for a Brownian particle — 59
2.1.1	Nature of motion of a Brownian particle. Random forces — 59
2.1.2	Displacement of a Brownian particle — 64
2.2	The Fokker–Planck equation for a Brownian particle — 67
2.2.1	Derivation of the Fokker–Planck equation — 67
2.2.2	The solution of the Fokker–Planck equation — 69
	Problems to Chapter 2 — 73

3	Kinetic equations in non-equilibrium statistical mechanics — 74
3.1	Description of non-equilibrium systems in statistical mechanics — 74
3.1.1	Integrable and nonintegrable dynamical systems — 74
3.1.2	The evolution of dynamical systems in phase space — 76
3.2	Substantiation of quasiclassical kinetic equations — 82
3.2.1	The Liouville equation for the distribution function — 82
3.2.2	The chain of the Bogoliubov equations — 84
3.2.3	Equation for the one-particle distribution. The relaxation time approximation — 88
3.2.4	The Vlasov kinetic equation for a collisionless plasma — 89
3.2.5	The Boltzmann equation for a low-density gas — 96
3.2.6	Qualitative derivation of the Boltzmann equation — 97
3.2.7	Derivation of the Boltzmann equation from the Bogoliubov equations chain — 103
3.2.8	The Fokker–Planck equation — 106
3.3	Solving for kinetic equations — 110
3.3.1	The solution of the Boltzmann equation for the equilibrium state — 110
3.3.2	The Boltzmann H -theorem — 112
3.3.3	The Hilbert expansion — 114
3.3.4	The Enskog–Chapman method. Derivation of hydrodynamic equations — 120
3.3.5	The method of moments — 125
	Problems to Chapter 3 — 127
4	Kinetic equation for electrons and phonons in conducting crystals — 129
4.1	Kinetic coefficients in the relaxation time approximation — 129
4.1.1	Kinetic equation for electrons and its solution to the relaxation time approximation — 129
4.1.2	Conditions of applicability for the quasi-classical description of electrons in conducting crystals — 134
4.1.3	How to determine charge and heat fluxes and calculate kinetic coefficients when $H = 0$ — 137
4.1.4	Scattering of electrons by lattice vibrations — 147
4.1.5	The Hamiltonian of interaction between electrons and charged impurity centers — 151
4.1.6	The collision integral for the electron-phonon interaction — 153
4.1.7	Phenomenon of phonon drag — 158
4.1.8	Expressions for charge and heat fluxes in a magnetic field. Tensor structure of kinetic coefficients — 162
4.1.9	Galvanomagnetic and thermomagnetic effects in semiconductors with a parabolic dispersion law — 164

4.2	Hydrodynamic description of a hot electrons —	169
4.2.1	Transition to a hydrodynamic description —	169
4.2.2	The momentum balance equation —	172
4.2.3	Balance equations of energy and particle number —	178
4.2.4	Solving a set of balance equations. Applications of hydrodynamic approach —	180
4.2.5	Negative differential resistance —	182
	Problems to Chapter 4 —	186
5	Theory of linear response to an external mechanical perturbation —	189
5.1	Electrical conductivity of an electron gas. The Kubo method —	189
5.1.1	The Liouville equation and its solution —	189
5.1.2	Linear response of a dynamical system to an external field —	193
5.1.3	Calculation of electrical conductivity —	197
5.1.4	High-frequency magnetic susceptibility —	207
5.2	Electrical conductivity in a quantizing magnetic field —	214
5.2.1	Charge and heat fluxes in a quantizing magnetic field —	214
5.2.2	Dynamics of electron motion in a quantizing magnetic field —	216
5.2.3	The conductivity tensor in a quantizing magnetic field —	218
5.2.4	The conductivity in the case quasielastic scattering by phonons —	221
5.3	Symmetry properties of correlation functions —	227
5.3.1	Additive conservation laws and selection rules for averages —	227
5.3.2	Symmetry properties of correlation functions for operations of spatial rotation, complex conjugation and time reversal —	230
	Problems to Chapter 5 —	235
6	Non-equilibrium statistical operator method —	238
6.1	Non-equilibrium and quasi-equilibrium statistical operators —	238
6.1.1	Quasi-equilibrium distribution —	238
6.1.2	Extremal properties of a quasi-equilibrium distribution. Thermodynamics of a quasi-equilibrium ensemble —	241
6.1.3	Boundary conditions and the Liouville equation for the NSO —	248
6.1.4	Linear relaxation equations in the NSO-method —	251
6.2	The projection operators method in non-equilibrium statistical mechanics —	256
6.2.1	Why is it necessary to introduce projection operators? —	256
6.2.2	The Mori projection operator method —	260
6.2.3	Using the Mori projection operators to calculate conductivity —	267
6.2.4	Relationship between a linear variant of the NSO-method and Mori's method —	274
6.2.5	High-frequency susceptibility —	277

6.2.6	Determination of non-equilibrium parameters by the NSO-method — 279
6.3	Hydrodynamic modes and singularity of dynamic correlation functions — 285
6.3.1	Spin diffusion — 285
6.3.2	The fluctuation-dissipation theorem — 289
6.3.3	Long-range correlations and slow modes — 294
6.3.4	Bogoliubov inequality and $1/k^2$ divergence theorem — 298
	Problems to Chapter 6 — 304

7 Response of a highly non-equilibrium system to a weak measuring field — 307

7.1	NSO for highly non-equilibrium systems — 307
7.1.1	Set up of the problem. A boundary condition for the NSO — 307
7.1.2	Generalized susceptibility of a non-equilibrium system — 313
7.2	Projection operator for non-equilibrium systems — 317
7.2.1	Magnetic susceptibility — 317
7.2.2	Electrical conductivity of highly non-equilibrium systems — 319
	Problems to Chapter 7 — 337

8 Master equation approach — 338

8.1	The basic idea of the method — 338
8.1.1	Problem statement — 338
8.1.2	The Zwanzig kinetic equation — 339
8.2	Master equation for the quasi-equilibrium distribution — 342
8.2.1	Robertson projection operator — 342
8.2.2	Use of the master equation to calculate kinetic coefficients — 345
	Problems to Chapter 8 — 350

Bibliography — 353

Index — 355