

Contents

Preface	xiii
Acknowledgments	xv
Introduction: aims and scope	xvii
Chap. 1 Physical significance of Nöther's symmetries and extremum principles	1
1. 1 Necessary conditions for a functional extremum	1
1. 2 The inverse problem of variational calculus	7
1. 3 Hamilton's principle, Nöther's theorems and physical symmetries	13
1. 4 Nonequilibrium thermo-hydrodynamics and extremum principles	20
Chap. 2 Eulerian and Lagrangian descriptions of perfect fluids	26
2. 1 Variational derivation of Euler equation in spatial representation	26
2. 2 Balances of momentum and energy in perfect fluids	30
2. 3 Physical Lagrangian of the perfect fluid	35
2. 4 Meaning and properties of Lagrangian multipliers	39
2. 5 Connection between Eulerian and Lagrangian descriptions	41
2. 6 A theory with continuity equation built-in lagrangian	46
2. 7 Extended descriptions involving thermal phase	50
2. 8 Relabeling symmetries and vorticity conservation laws	55
2. 9 Introduction to Poissonian brackets and reduction theories	59
2. 10 Noncanonical Poisson brackets for ideal magneto-hydrodynamics	62
2. 11 Bibliographic notes	64

Chap. 3 Conservation laws for given system of equations	72
3. 1 Adjoint variables and variational principles	72
3. 2 Generalized Nöther's theorem and conservation laws	74
3. 3 Discussion	76
3. 4 Application to Euler equations	77
3. 5 Navier-Stokes equations	82
Chap. 4 Thermodynamics and kinetics of nonequilibrium fluids	87
4. 1 Fluids at local equilibrium: an outline of the classical theory	87
4. 2 Fluids without local equilibrium: an introduction	92
4. 3 Thermodynamics of nonequilibrium fluids with heat flow	93
4. 4 Nonequilibrium energy correction from the kinetic theory	96
4. 5 Nonequilibrium energy and kinetic potential for fluids with heat	101
4. 6 Irreversible heat conduction and diffusion of mass	104
4. 7 Chemical kinetics in terms of chemical resistances	109
4. 8 Solving difficulties in kinetics and dynamics of electrochemical systems	118
4. 9 Electrochemical kinetics as extension of classical concepts	120
Chap. 5 Lagrangian and Hamiltonian formalism for reversible nonequilibrium fluids with heat flow	129
5. 1 Conservation laws for fluids with heat flow: an introduction	129
5. 2 The variational approach through Hamilton's principle	131
5. 3 Constraints and Lagrangian multipliers	133
5. 4 Extremum conditions of the action	134
5. 5 Application of Nöther's theorem	135
5. 6 Invariant non-equilibrium quantities and significance of thermal momentum	140
5. 7 Compatibility with kinetic theory	144

5. 8	Hamiltonian approach	145
5. 9	Concluding remarks	148
Chap. 6	Extended reversible problem involving mass diffusion, heat flow and thermal inertia	150
6. 1	New approach to the problem of thermal inertia	150
6. 2	Kinetic potential, constraints and action	156
6. 3	Extremum conditions of action and the pressure lagrangian	159
6. 4	Application of Nöther's theorem	162
6. 5	Stress tensor and momentum balance	163
6. 6	Energy flux and various definitions of heat	165
6. 7	Energy density and energy balance	169
6. 8	Gibbs equations of thermo-hydrodynamics for fixed (\mathbf{x} , t)	170
6. 9	Significance of Lagrangian multipliers	177
6. 10	Legendre transformations and thermodynamic potentials for variable \mathbf{x} and t	180
6. 11	Gradient representations and phase-dependent thermodynamics	187
Chap. 7	A generalized action with dissipative potentials	194
7. 1	Motion from a lagrangian incorporating entropy source	194
7. 2	Heat transfer in terms of lagrangian, dissipative potentials and constraints	198
7. 3	Stationarity conditions of action and gradient representations	204
7. 4	Nöther's energy for fluids with irreversible heat flow	209
7. 5	Fundamental equation for dissipative fluid with heat flow	210
7. 6	Dynamics through fundamental equation I- Hamiltonian	212
7. 7	Macroscopic view of heat and equations of heat transfer	217
7. 8	Conservation laws dependent on thermal phase	219

7. 9.	Dynamics through fundamental equation II - Poissonian brackets	221
7. 10	Testing models of entropy sources	223
7. 11	Thermo-optical analogies and heat pulse propagation	236
Chap. 8	Thermo-hydrodynamic potentials and geometries: the union of thermodynamics and hydromechanics	241
8. 1	Reversible case: no Clebsch variables	241
8. 2	Irreversible case: Clebsch variables explicit	246
8. 3	Duality and equivalence of action and entropy representations	253
8. 4	Thermodynamic geometries	257
8. 5	Field thermo-hydrodynamic metric from a potential	264
Chap. 9	Intrinsic symmetries and conservation of mass in chemically reacting systems	268
9. 1	Towards lagrangian of multicomponent system with chemical reactions	268
9. 2	Generalized variational scheme, equations of motion and conservation laws	270
9. 3	Intrinsic symmetries and irreversibility	278
9. 4	Irreversible heat conduction and self-diffusion in energy representation	281
9. 5	Vector external fields interacting with charged particles	284
9. 6	Conventional postulate constraining irreversible processes	288
9. 7	Nonlinear chemical kinetics in the context of action functional	294
9. 8	Kinetics of heat transfer and its relation to standard results	297
9. 9	Matter tensor and conservation laws modified by dissipation	299
9. 10	Distributed chemical kinetics coupled with mechanical motion	301
9. 11	Concluding remarks	308

Chap. 10 Conservation laws as given constraints for processes at mechanical equilibrium	312
10. 1 A concept of minimum integrated power as an alternative to least action	312
10. 2 An example in dynamics of lumped networks	314
10. 3 Systems with inertial terms	320
10. 4 Nonisothermal processes	324
10. 5 Extremum properties of transport phenomena in continuous systems	328
10. 6 Balance equations and irreversible thermodynamics	332
10. 7 Error and entropy functionals as the second law criteria	335
10. 8 Link with Onsager's criterion	337
10. 9 Discussion	338
10. 10 Inclusion of inertial terms and uniform motion	340
10. 11 Damped wave equations as extremum conditions	342
10. 12 Towards field thermodynamic hamiltonian and Poissonian brackets	345
10. 13 Thermodynamic hamiltonian	347
10. 14 Thermodynamic lagrangian Λ_{σ} and duality of two basic formulations	351
10. 15 Hamiltonian theory of Fourier's equations of heat transfer	352
Chap. 11 Generalized minimum dissipation in presence of convection and chemical reactions	356
11. 1 Generalized integral principle involving entropy production	356
11. 2 Extremum conditions of thermodynamic action	359
11. 3 Local principles for rate processes and surface kinetics	363
11. 4 Concluding remarks	367

Chap. 12 Some associated relativistic results

12. 1	Outline of standard relativistic theory	369
12. 2	Transformation of thermodynamic intensities	371
12. 3	Thermal momenta of classical nonequilibrium thermodynamics	374
12. 4	The hypothesis of thermal mass	377
12. 5	Thermal momenta of extended thermodynamics	384
12. 6	Energy and entropy relations and nonequivalence of representations	386
12. 7	Heat transfer with finite propagation speed	389
12. 8	Extension of Ray's analysis including effect of heat	392
12. 9	Bibliographic notes on relativistic systems	396
12. 10	Final remarks	398

References	401
-------------------	------------

Glossary of principal symbols	439
--------------------------------------	------------

Index	443
--------------	------------