

Contents

Preface	vii
9 Micropolar Fluid Dynamics	1
9.0 Scope	1
9.1 Motion, Micromotion	3
9.2 Strain and Rotation Measures	6
A. Deformation Tensors	6
B. Microrotation	7
C. Deformation-Rate Tensors	7
D. Objectivity (Material-Frame Indifference)	9
E. Compatibility Conditions	9
F. Linear Strain Measures	10
9.3 Balance Laws of Micropolar Fluids	11
9.4 Constitutive Equations of Isotropic Micropolar Fluids	13
9.5 Field Equations	15
9.6 Passage to Classical Fluid Dynamics	19
9.7 Pipe Flow	20
9.8 Similarity Parameters	24
9.9 Micromotion and Vortices	26
9.10 A Micropolar Description of Turbulence	28
9.11 Kampé de Fériet and Taylor Solutions	32
9.12 Flow in a Rheometer	36
9.13 Lubrication	42
9.14 Fundamental Solutions for Slow Motions	46

9.15	Stokes Flow About a Sphere	51
9.16	Stagnation Flow	54
9.17	Thermal Instability of a Layer of Micropolar Fluid	58
	A. Linear Steady Stability	60
	B. Oscillatory Convection	61
9.18	Boundary Layer Flow Over a Plate	64
9.19	Mixed Convection in Vertical Flow	73
9.20	Invariant Solutions of Plane Micropolar Flows	77
	Chapter 9 Problems	80
10	Electrodynamics of Micropolar Fluids	83
10.0	Scope	83
10.1	Balance Laws	84
	A. Maxwell's Equations	84
	B. Balance Laws of Micropolar Continua	85
10.2	Constitutive Equations	87
10.3	Thermodynamic Stability	88
10.4	Field Equations	89
10.5	Magneto-Micropolar Fluid Mechanics	90
10.6	Perfect Magneto-Micropolar Hydrodynamics	94
10.7	Channel Flow of Magneto-Micropolar Fluids	95
10.8	Shear Flow of M^2HD	97
10.9	Magneto-Micropolar Fluids Heated from Below	98
10.10	Micropolar Electro-hydrodynamics	101
	A. Field Equations	102
10.11	MEHD Flow in a Channel	104
	Chapter 10 Problems	105
11	Anisotropic Fluids and Suspensions	107
11.0	Scope	107
11.1	Balance Laws	108
11.2	Constitutive Equations	108
11.3	Thermodynamic Stability	110
11.4	Field Equations	112
11.5	Anisotropic Navier-Stokes Fluids	113
11.6	Channel Flow of Anisotropic Navier-Stokes Fluids	115
11.7	Anisotropic Fluids and Suspensions	117
	A. Microinertia Balance Law	117
	B. Balance of Momenta and Energy	119
	C. Constitutive Equations	122
	D. Field Equations	123
11.8	Dense Fiber Suspensions	124
	A. Suspension in Newtonian Fluids	126
	B. Rigid Fiber Suspensions in Newtonian Fluids	127
11.9	Channel Flow of Fiber Suspensions	127

11.10	Couette Flow of Rigid Bar Suspensions	131
	Chapter 11 Problems	134
12	Liquid Crystals	135
12.1	Liquid Crystalline State	136
12.2	Order Parameter	141
12.3	Kinematics of Liquid Crystals	145
12.4	Balance Laws of Liquid Crystals	148
12.5	Constitutive Equations	149
12.6	Constitutive Equations of Nematic Liquid Crystals	153
	A. Static Constitutive Equations	153
	B. Dynamic Constitutive Equations	155
	C. Constitutive Equations of Isotropic Elastic Liquid Crystals	156
12.7	Thermodynamic Stability	158
	A. Thermodynamic Restrictions for Isotropic Liquid Crystals	161
12.8	Constitutive Equations of Cholesteric Liquid Crystals . .	161
	A. Static Constitutive Equations	161
	B. Dynamic Constitutive Equations	162
12.9	Smectic Liquid Crystals	166
12.10	Oseen–Frank Theory	169
12.11	Passage from E Theory to O–F Theory	171
	A. Balance Laws	172
	B. Constitutive Equations	173
12.12	A Critical Assessment	176
12.13	Field Equations of Nematic Liquid Crystals	181
	A. Field Equations Using γ and $\mathbf{j}$	181
	B. Field Equations Using Variables $\mathbf{n}$ and ϕ	183
	C. Boundary Conditions	183
12.14	Special Motions	184
	A. Axis of Rotation $\mathbf{n}$ Remains Fixed in the Same Direction	184
	B. Axis of Rotation $\mathbf{n}$ Remains in a Plane	189
12.15	Field Equations of Isotropic Liquid Crystals	191
12.16	Quasi-Linear Theory	193
	Chapter 12 Problems	194
13	Electrodynamics of Liquid Crystals	197
13.0	Scope	197
13.1	Balance Laws	198
	I. Maxwell’s Equations	198
	II. Mechanical Balance Laws	199

13.2	E-M Constitutive Equations of Nematic Liquid Crystals	201
	A. Static Constitutive Equations	203
	B. Dynamic Constitutive Equations	205
13.3	Electrodynamics of Cholesteric Liquid Crystals	207
	A. Static Constitutive Equations	207
	B. Dynamic Constitutive Equations	208
	C. Thermodynamic Stability	209
13.4	Passage to Director Theory	210
13.5	Electrodynamics of Smectic Liquid Crystals	211
	Chapter 13 Problems	212
14	Selected Problems in Liquid Crystals	213
14.0	Scope	213
14.1	Ideal Hydrodynamics of Nematic Liquid Crystals	214
	A. Plane Motions	214
	B. Antiplane Motions	215
14.2	Twisting Nematic Fibers Between Two Parallel Plates	216
14.3	Twist Waves	216
14.4	Shear Flow of Nematics	217
14.5	Magnetic Coherence Length	220
14.6	Fredericks Transition	221
14.7	Flexoelectric Effect	223
14.8	Heat Conduction in a Channel Flow	225
14.9	Disclinations	226
14.10	Solutions of Some Problems in Isotropic Liquid Crystals	232
	A. Orientation Waves	233
	B. Orientation of Molecules in Channel Flow	233
	C. Shear Flow	234
	D. Response of Orientation to Impluse	235
	Chapter 14 Problems	236
15	Microstretch Fluids	237
15.0	Scope	237
15.1	Kinematical Preliminaries	237
15.2	Balance Laws	238
15.3	Constitutive Equations of Microstretch Fluids	240
15.4	Field Equations	243
	A. Boundary Conditions	244
	B. Initial Conditions	245
15.5	Acoustic Waves in Bubbly Fluids	246
15.6	Blood Flow in Small Arteries	250
	Chapter 15 Problems	253

16 Electrodynamics of Polymeric Liquid Crystals	255
16.0 Scope	255
16.1 Balance Laws	256
A. Mechanical Balance Laws	256
B. E–M Balance Laws	258
16.2 Second Law of Thermodynamics	259
16.3 Constitutive Equations	259
16.4 Quasi-Linear Constitutive Equations of Nematic Liquid Crystals	263
A. Static Constitutive Equations	263
B. Dynamic Constitutive Equations	265
16.5 Thermodynamic Stability	267
16.6 Constitutive Equations of Smectic Liquid Crystals	268
16.7 Constitutive Equations of Cholesteric Polymers	269
A. Static Constitutive Equations	269
B. Dynamic Constitutive Equations	270
16.8 Question of Closure	273
16.9 Nonlinear Rheology	273
A. Static Constitutive Equations	273
B. Dynamic Constitutive Equations	275
Chapter 16 Problems	277
 17 Micromorphic Fluids	 279
17.0 Scope	279
17.1 Kinematical Preliminaries	280
17.2 Balance Laws	281
17.3 Constitutive Equations	282
17.4 Linear Constitutive Equations	283
17.5 Field Equations	285
17.6 Incompressible Micromorphic Fluids	287
17.7 Channel Flow	288
17.8 Effect of Microstructure on the Rheology of Blood	292
17.9 Micromorphic Theory of Turbulence	300
A. Balance Laws	302
B. Constitutive Equations	305
C. Field Equations	308
D. Incompressible Fluids	309
17.10 Turbulence in Newtonian Fluids	311
17.11 Deformable Suspensions	313
Chapter 17 Problems	317
 References	 319
 Index	 331

Errata for <i>Microcontinuum Field Theories I. Foundations and Solids</i>

341