## Index

A	spherical coordinate, 122, 129, 132
Acceleration, 62	von Mises, 122
material motion, 62, 63	Cayley-Hamilton theorem, 35
rigid body rotation, 62, 63	Characteristic equation, 30
Airy function, 183	Cayley-Hamilton theorem, 35
Analog model, 208, 218	matrix polynomials, 35
Angular momentum, 4	Christoffel symbol, 48, 49
Angular velocity, 94	Classical field theories, 9
<i>g.</i>	Clausius-Duhem inequality, 139
В	differential forms, 153
-	integral forms, 153
Bauschinger effect, 234	Complex modulus, 228
Beltrami-Michell compatibility	Conservation laws, 153
equation, 176	Conservation of energy, 148
Bernoulli's equation, 189	Conservation of linear momentum
Bernoulli's principle, 8	cylindrical coordinates, 147
Biharmonic equation, 176, 179	spherical coordinates, 147
Body force, 111, 143	Conservation of mass, 141
Boundary element methods, 10	differential statement, 141
Boundary-value problem	Lagrangian, 141
displacement problem, 175	principle of, 141
mixed problem, 175	Conservation of momentum, 146
traction problem, 174	Constitutive equation
_	axioms, 293
C	consistency, 294
Cartesian coordinate system, 268	coordinate invariance, 294
alternating symbol, 25	determinism, 294
components, 22	equipresence, 294
definition, 44	integral models
orthonormal basis, 18	K-BKZ, 321
unit basis vectors, 28	single deformation tensor, 319
Cartesian tensor, 21	linear isotropic elastic materials, 345
components of, 21, 22	local action, 294
divergence theorem, 40	material frame-indifference, 294
localization theorem, 40	nonlinear finite elasticity
stokes theorem, 40	constitutive laws, 297
Cauchy's equation, 144	general formulation, 297
Cauchy stress tensor, 114	simple shear deformation, 303
axes, 118	torsion, 306
Biot, 130	uniaxial loading, 295, 299
contour lines, 123	nonlinear viscous
corotational, 131	incompressible simple fluids, 313
cylindrical coordinate, 132	Reiner-Rivlin fluid, 309
deviatoric, 122	Rivlin-Ericksen fluid, 311
distributions, 123	simple incompressible fluid, 310
Kirchhoff, 130	principles of, 293
objectivity, 131	setting, 294
octahedral, 122	simple materials, 296
Piola-Kirchhoff, 127	symmetry, 294
principal stresses, 118	thermoviscous fluid, 295

Constitutive equations, 160	polar coordinate system, 270
classical plastic materials	poroelasticity
constitutive law, 234	dual stress distribution, 278
stress-strain relations, 243	linear isotropic, 280
yield function, 237	parameters, 278
correspondence principle, 226	stress field calculations, 267
harmonic response, 228	thermoelastic solids, 264
ideal fluid	Continuity equation, 141
constitutive law, 187	Continuum damage mechanics
general formulation, 188	(CMD), 368
problem solutions, 190	goal of, 368
linear elasticity	hydrostatic stresses, 373
antiplane strain, 177	numerical evaluation, 371
biharmonic operator, 179	one-dimensional deformation, 369
boundary conditions, 173	plot of, 371
displacement problem, 175	RVE, 368
Euler description, 164	strain equivalence principle, 369
hydrostatic compression, 171	stress-strain curve, 371
hyperelastic material, 165	thermodynamic principles, 372
infinitesimal theory, 163	Continuum hypothesis, 1
isotropic material, 168	Continuum mechanics
Lagrangian description, 164	alternating symbol, 15
linear elasticity model, 172	antisymmetric symbols, 14
microstructural symmetries, 166	body forces, 111, 112
mixed problem, 175	cartesian tensors, 21
monoclinic material, 166	cauchy stress principle, 113
orthotropic material, 167, 168	cauchy stress tensor, 114
plane strain, 177	circular, 41
plane stress, 177	classical field theories, 9
proportional limit, 162	coordinate, 17
pure shear, 170	cylindrical, 41
simple tension test, 162, 170	determinants, 16
stress formulation, 175	direct notation, 11
traction problem, 174	finite difference method, 10
yield point, 162	index notation, 11
linear viscous fluids	Kronecker delta, 15
constitutive law, 195	mass density, 4, 5
couette flow, 201, 202	matrix algebra, 27
general formulation, 198	nonlinear field theories, 9
Hagen-Poisueille flow, 203	orthogonal transformations, 19
plane poiseuille flow, 199	predicting macroscopic material, 2
microstructure, 160	reference frame, 25, 26
types of, 159	representation theorem
Constitutive relation	scalar-valued, 36
Cartesian coordinate system, 268	tensor-valued, 36
compatibility equations, 267	representative elementary
displacement formulation, 267	volume, 2
electroelasticity	rheology, 9
applications of, 288	spherical, 41
linear elasticity model, 286	structure of, 1, 6, 7
Mandel's consolidation problem, 284	summation convention, 13
one dimensional consolidation, 281	surface forces, 111, 112

symmetric symbols, 14	E
tensors, 5	Eigenvalue, 30
theoretical aspects, 7	Elasticity
transformation laws, 21	asymmetric, 335
vector algebra, 27	CMD
vectors, 17	goal of, 368
Contour line, 123	hydrostatic stresses, 373
Correspondence principle	numerical evaluation, 371
elastic problems, 226	one-dimensional deformation, 369
viscoelastic problems, 226	plot of, 371
Couette flow, 201	RVE, 368
Covariant derivative, 48	strain equivalence principle, 369
Creep, 206	stress-strain curve, 371
Curvilinear coordinate system, 21	thermodynamic principles, 372
general tensors, 46	Cosserat continuum, 335
orthogonal, 41	doublet mechanics
Curvilinear cylindrical coordinate, 102	application, 352
Cylindrical coordinate system, 132	development of first-order, 352
motion equation, 147	flamant problem, 352, 353
	granular interpretation, 350
_	microstresses, 350
D	order of approximation, 351
Dashpot, 209	gradient elasticity
Deformation gradient tensor	flamant problem, 359
extensional motion, 66	screw dislocation, 356
homogeneous, 67	granular material
nonhomogeneous, 67	complexity of, 368
objectivity test, 69	continuum descriptions, 363
orthogonal triad, 76	fabric theories, 361
simple shearing motion, 66	force distribution, 367
Del operator, 39	load transfer, 362, 363
Determinant, 16	local fabric, 362
Determinism, 294, 297	stress distribution, 362
Dilatancy, 361	micromechanics material modeling, 331
Dirac delta function, 209	micropolar, 334
Discrete element modeling, 363	oriented media, 335
Displacement. See also	screw dislocation, 356
Kinematics	voids, 344
continuum motion, 64	Electroelasticity, 286
extensional motion, 66	applications of, 288
nonhomogeneous deformation, 67	linear theory, 287
simple shearing motion, 66	Entropy, 151
Divergence theorem, 40, 140, 144	Euler-Cauchy differential equation, 193
Dot product, 27	Eulerian strain tensors
Doublet mechanics (DM), 350	extensional deformations, 72
application, 352	simple shear deformations, 72
development of first-order, 352	Euler's equation, 188
flamant problem, 352, 353	,
granular interpretation, 350	-
microstresses, 350	F
order of approximation, 351	Finite difference methods, 10
Dyadic, 22	Finite element methods, 10

F: (1 6d 1 : 140	P. J.
First law of thermodynamics, 148	displacement
Fourier transform, 357	continuum motion, 64
_	extensional motion, 66
G	nonhomogeneous deformation, 67
Granular material	simple shearing motion, 66
complexity of, 368	eulerian descriptions, 60
continuum descriptions, 363	eulerian strain tensor, 69
fabric theories, 361	lagrangian, 69
force distribution, 367	lagrangian descriptions, 60
load transfer, 362, 363	material body, 57
local fabric, 362	material time derivative, 61
stress distribution, 362	motion, 57
	objective time derivatives, 97
Н	reference configuration, 99
Helmholtz free energy, 264	Rivlin-Ericksen tensors, 101
Homogenization, 332	rotation tensor, 91
Hooke's law, 164, 181	small deformation, 83
isotropic form, 221	spherical coordinate, 102
Voigt notation, 164	strain compatibility, 86
Hysteresis, 206	strain tensors
Trysteresis, 200	deviatoric, 85
1	principal axes, 85
1	spherical, 85
Integrability, 86	velocity, 62
Integral model	volume elements, 80
K-BKZ, 321	Kronecker delta, 15
single deformation tensor, 319	components of, 25
Inviscid flow, 188, 191	orthogonality relation, 25
Isostatic, 124	permutation symbol, 16
Isotropic, 37	properties of, 20
_	substitution property, 16
J	symmetric symbol, 15
Jacobian determinant, 57	
control volume, 139	L
material volume, 139	Lagrangian, 69
	extensional deformations, 72
K	simple shear deformations, 72
Kelvin's Theorem, 188	Laminar flow, 196
Kelvin-Voigt model, 212	Laplace's equation, 190, 191
constant loading rate response, 215	Laplace transforms, 227
creep functions, 210, 212	Leibniz integral rule, 223
loading response, 216	Linear elasticity, 162
relaxation, 212, 213	antiplane strain, 177
strain recovery, 214	biharmonic operator, 179
stress-strain response, 216	boundary conditions, 173
unloading response, 216	constitutive law, 162
Kinematics	displacement problem, 175
acceleration, 62	dynamic problems, 187
area, 80	Euler description, 164
changes in line, 80	general formulation
curvilinear cylindrical coordinate, 102	displacement formulation, 198
deformation gradient tensors, 64	stress formulation, 175

hydrostatic compression, 171	constitutive laws, 297
hyperelastic material, 165	general formulation, 297
infinitesimal theory, 163	simple shear deformation, 304
isotropic material, 168	torsion, 307
Lagrangian description, 164	uniaxial loading, 299
linear elasticity model, 172	No-slip condition, 199
microstructural symmetries, 166	•
mixed problem, 175	0
monoclinic material, 166	Objectivity, 25
orthotropic material, 167, 168	Orthogonal transformation, 19
plane strain, 177	Orthotropic material, 167
plane stress, 177	
problem solutions, 177	P
proportional limit, 162	Parallelogram rule, 18
pure shear, 170	Photoelasticity, 123
simple tension test, 162, 170	Plasticity, 234
stress formulation, 175	Poisson's ratio, 229, 372
traction problem, 174	Polar coordinate system, 270
yield point, 162	curvature of, 45
Linear momentum, 4	two-dimensional, 45, 49
Localization theorem, 40	Polar decomposition theorem, 73
	Poroelasticity, 263, 277
M	dual stress distribution, 278
MATLAB, 23, 190, 199	linear isotropic, 280
Matrix algebra, 27	parameters, 278
Matrix polynomial, 35	Potential function, 189
Maxwell model, 209, 210	derivative of, 244
analog constitutive forms, 223	governing equations, 225
creep functions, 210	integrating relations, 192
integral constitutive forms, 228	Pull-back operation, 79
relaxation, 210	Push-forward operation, 79
single relaxation time function, 223	•
strain recovery, 214	R
Michell solution, 179	Radial distribution function, 185
Microstructure, 160	Repeating unit cell (RUC), 332
cellular materials, 160, 161	Representative volume element (RVE)
composite materials, 160	composite materials, 332
homogeneity, 161	definition of, 332
isotropy, 161	Reynold's number, 196
porous materials, 160, 161	Reynolds transport theorem, 139
in solids, 160	conservation laws, 153
Mohr's circle, 121	conservation of energy, 148
Motion, 57	conservation of linear momentum
Motion equation, 147	cylindrical coordinates, 147
M	spherical coordinates, 147
N	conservation of mass, 141
Nanson's formula, 81	general principles, 153
Navier-Stokes equations, 8, 309	Rheology, 9
classical fluid mechanics, 198	deformation, 309
nonlinear, 198	flow, 309
Nonlinear field theories, 9	Rivlin-Ericksen tensor, 101
Nonlinear finite elasticity	Rotation tensor, 91

\$	T
Saint Venant compatibility	Taylor series, 311
equation, 88	Tension, 171, 246
Scale factor, 42	Tensor, 5
Second law of thermodynamics, 151	isotropic, 37
Shear flow, 196, 197	physical components, 43
Silly Putty, 206	Thermodynamic
Simple shear	potential
area, 80	free energy, 265
fluid models, 312	nonthermal hyperelastic equation, 264
K-BKZ viscoelastic fluid, 322	second law of, 139
line, 80	Torsion
relative deformation, 100	cylindrical bar, 249, 250
stress power calculation, 150	elastic cylinder, 306, 307
volume changes, 82	Traction, 173
Solid mechanics, 8	Transformation law, 21
Spherical coordinate system, 102, 132	alternating symbol, 25
motion equations of, 148	coordinate frame, 22
Stoke's theorem, 40, 188	first-order, 21
Strain tensor, 83, 85	matrix multiplications, 23
compatible, 90	second-order, 21
determination of, 90	
deviatoric, 85	V
incompatible infinitesimal, 90	Vector algebra, 27
principal axes, 85	Velocity, 62
rate of, 93	Viscoelasticity, 7
small deformation theory, 90, 102	analog, 208, 218
spherical, 85	creep function, 208, 209
Stream function	Kelvin-Voigt model, 212, 214
governing equations, 190	linear integral constitutive form, 221
Laplace's equation, 190	Maxwell model, 209
Streamline, 189	silly putty, 206, 207
Stress function, 176	stress relaxation, 207, 208
Stress relaxation, 206	Void, 344
Stress-strain curve, 162	elasticity, 346
plastic deformation, 163	microequilibrium, 345
yield point, 162	solid continuum, 344
Surface force, 111, 112	Volume fraction, 344
Symmetric second-order	Vorticity, 188
tensors	347
deviatoric, 34	W
diagonal element, 32	Work hardening, 234
directions, 29	
invariants, 29	Υ
polar decomposition theorem, 37	Yield surface
principal values, 29	Mises, 240, 241
spherical, 34	Tresca, 240, 241