

Subject Index

P-function 134, 135, 150

a

angle of inclination 87, 89
apparent viscosity 6, 206, 214
approximate integral method 209, 239
aqueous sucrose solution 209
asymptotic expression 36, 47
average Nusselt number 61, 63

b

Bingham fluid 6
Bingham plastic 2–4, 213, 214
Bingham plastic model 6
biological additive 5
Boger fluid 8
boundary layer 30, 102, 135, 145, 151, 230
boundary-layer flow 7, 133, 163, 164, 174
boundary-layer thickness 33, 78, 119, 133, 237
Boussinesq approximation 64, 110, 119, 168, 175, 183, 227, 232, 235, 238
Brinkman effect 164
Brinkman–Darcy equation 18
Brinkman–Darcy flow 19
Brinkman–Forchheimer equation 193
Brinkman–Forchheimer modification 195
Brinkman–Forchheimer-extended Darcy model 194
Brinkman-extended Darcy model 202
buffer layer 146, 158

bulk mean temperature 197

bulk mean velocity 197
buoyancy 98, 99, 112, 113
buoyancy force 13, 119, 145, 157, 213
buoyancy term 15
buoyant layer 157

c

carbopol solution 219
carboxymethyl cellulose 206
characteristic Grashof number 54, 106, 247
characteristic length 50, 74, 106, 236
characteristic Prandtl number 247
characteristic process time 150, 158
characteristic relaxation time 225
characteristic time 2, 9
characteristic velocity 13, 21, 59, 74, 106, 111, 227, 236
circular pipe 154
circular tube 131
coefficient of volume expansion 13, 22
Colburn's analogy 105
compatibility condition 76
complementary error function 239
computational tools 27
conduction 98, 112
cone 164
consistency index 5, 99, 132, 227
consistency indices 214
constant heat flux 215
constant temperature 206, 215
constant wall flux 219
constant wall heat flux 217

- constitutive equation 1, 5–7, 69, 72, 90, 222, 224
 continuity equation 20, 21
 convection 98, 112
 corn starch suspension 209
 critical wave number 243
 crude oil 4
- d**
 Darcian or superficial velocity 166, 182
 Darcian velocity 164
 Darcy convection 171
 Darcy equation 23
 Darcy flow 19, 164, 227, 238
 Darcy law 16–18, 232
 Darcy mixed convection 189
 Darcy model 202
 Darcy number 26, 194, 196
 Darcy regime 169, 227
 Darcy–Forchheimer flow 19, 165, 175
 Darcy–Forchheimer forced convection 164, 173
 Darcy–Forchheimer mixed convection 175
 Darcy–Forchheimer regime 169, 170, 178
 Deborah number 2, 9, 121, 150, 152, 158, 160
 deformation tensor 19
 deforming stress 3
 destabilizing effect 243
 dilatant 2, 4
 dilatant fluid 30, 39, 209, 217, 219, 228, 231, 250
 dimensionless group 23, 24, 26
 dimensionless number 24
 dimensionless parameter 24
 drag coefficient 134, 166
 drag reducing fluid 3
 drag reduction 5, 148, 153, 158
 drag-reducing fluid 9, 97, 118, 120, 121, 149, 150, 152–157
- e**
 earth's mantle 221
 eddy diffusivity 97
 effective shear 214
 effective thermal conductivity 197
 effective viscosity 105
 elastic fluid 7, 181
 elastic material 2
 elastic recovery 3
 elastic stress 15
 elastic sublayer 158
 elastic sublayer concept 158
 elasticity 3, 4, 225, 243
 elastico-viscous fluid 182
 Ellis fluid 6, 207, 223, 224
 Ellis model 6, 205, 207
 energy equation 20, 23, 32, 45
 energy rate dissipation concept 97
 enthalpy conservation 232, 233
- f**
 fading memory 3
 Fanning friction factor 152
 filled polymer system 4
 finite difference method 27
 finite element method 27
 finite volume method 27
 finite-difference 206
 finite-difference computation 223
 flat plate 29, 32
 flow behavior index 215, 223
 flow stability 217, 218, 220
 fluid consistency index 232, 235
 fluid density 12
 fluid relaxation time 150, 158
 forced convection 83, 86–89, 106, 144, 148, 156
 forced convection heat transfer 29
 Forchheimer convection 171
 Forchheimer effect 18, 164
 Forchheimer equation 18
 Forchheimer regime 169
 Forchheimer term 17, 164
 Forchheimer-extended Darcy model 195
 Fourier method 222
 free convection 83, 84, 86, 103, 105, 107, 113, 116, 117, 144, 156, 163
 free-stream velocity 43
 friction factor 8, 9, 131, 136, 149, 152, 217
 friction velocity 121
 frictional resistance 165, 181

g

- generalized Reynolds number 136
 governing equation 11, 13, 16
 Graetz number 214
 Grashof number 24, 26, 74, 75, 160,
 247
 gum solution 4

h

- heat transfer analogy 131
 Hedstrom number 213
 Herschel–Bulkley fluid 6, 164, 227, 238
 Herschel–Bulkley power-law fluid 238
 high shear stress 207
 horizontal cylinder 78, 81, 89, 92–94,
 163, 164, 208, 209
 horizontal layer 222, 223, 241
 horizontal porous layer 241
 horizontal tube 144, 214
 hydrodynamic stability 220, 223

i

- inelastic non-Newtonian fluid 143
 inertia 98, 99, 112, 113
 instability analysis 221
 integral formulation 27
 integral method 27, 69, 104
 interpolating equation 83
 intrinsic permeability 167
 isothermal flat plate 34, 36, 87, 154
 isothermal inclined flat plate 86
 isothermal sphere 211

k

- kinematic viscosity 9, 121, 123

l

- lag 3
 laminar flow 214
 laminar sublayer 145, 149
 lattice Boltzmann method 27
 Legendre function 43
 length scale 26
 Levich's three-zone concept 97
 Levich's three-zone model 132
 linear stability theory 223
 local density 12
 local Nusselt number 61, 63

- local skin friction 37, 45
 low shear stress 207

m

- Mangler-type transformation 211
 maximum drag reduction 9, 121, 152,
 160
 maximum drag reduction asymptote
 10, 122, 152
 Maxwell fluid 7, 225, 243
 Maxwell model 225
 method of separation of variables 222
 mildly elastic behavior 3
 miscellaneous 205
 mixed convection 83, 86, 87, 89, 94,
 144, 148, 157, 164, 175, 178, 181,
 216, 220
 modified Darcy law 23
 modified permeability 16, 167
 momentum boundary layer 56, 73, 76,
 98, 157, 212

- momentum boundary-layer thickness
 73, 75

- momentum equation 20, 21
 momentum/heat transfer 143
 Momentum/Heat Transfer Analogy
 131
 momentum/heat transfer analogy 144,
 149, 152

n

- nanofluid 245
 natural convection 87, 90, 92–94, 97,
 98, 100–103, 109, 175, 177, 183,
 205, 227, 234, 240, 241, 245
 natural convective flow 232
 Newton–Raphson method 47
 Newton–Raphson shooting technique
 48
 Newtonian behavior 1, 221
 Newtonian fluid 1, 6, 7, 17, 19, 23, 24,
 34, 46, 87, 88, 93, 97, 101, 126,
 131, 133, 135, 149, 163, 166, 169,
 172, 190, 207, 213, 218, 220,
 223–225, 232, 241, 242
 Newtonian region 207
 Newtonian viscosity 1, 19
 non-Darcy flow 19, 20, 22, 164

- non-Newtonian behavior 2, 3, 102, 216, 217, 245
 non-Newtonian flow 220
 non-Newtonian fluid 1, 3–5, 11, 18, 24, 97, 104, 113, 213, 214, 219, 220, 224, 241
 nondimensional temperature 24
 normal stress 15
 numerical analysis 206
 numerical result 206
 numerically 228, 237
 Nusselt number 24, 35, 47, 58
- o**
 Oldroyd fluid 7, 70, 225, 241, 244
 Oldroyd model 7
 onset of convection 241, 243
 order of magnitude 225
 order of magnitude analysis 22, 53, 145
 oscillatory 222
 oscillatory convection 225, 241
 oscillatory flow 222
 oscillatory instability 242–244
 Ostwald–de Waele power-law behavior 7, 73
 Ostwald–de Waele power-law fluid 5
 Ostwald–de Waele power-law model 6
 overstability 222, 225
 overstable motion 243
- p**
 parallel plate 221
 partial differential equation 237
 particle diameter 166
 Peclet number 24, 25
 permeability 18
 plastic viscosity 6, 213
 Pohlhausen's polynomial 31
 Poiseuille flow value 204
 polyethylene 206
 polymer 5
 polymer melt 4
 polymer solution 4, 211, 212, 225
 porous inertia effect 18, 164
 porous inertia term 18
 porous media 17, 24, 163, 181, 193, 194
 porous medium 165, 168, 180, 202, 234, 235, 238, 241, 242
 power law fluid 87
 power-law exponent 32
 power-law flow index 248, 249
 power-law fluid 8, 16–18, 20, 22–25, 42, 83, 86, 87, 98–102, 112, 113, 131–133, 135, 136, 143–145, 147, 148, 157, 164, 165, 167, 168, 193–195, 205, 214, 215, 217, 224, 227, 231, 232, 234, 235, 240, 241
 power-law index 16, 132, 167, 180, 218, 227, 232, 235, 237
 power-law model 98, 132, 207
 Prandtl mixing length 132
 Prandtl number 24, 34, 46, 49, 75
 printing ink 4
 process time 9
 pseudoplastic 2, 4
 pseudoplastic behavior 3
 pseudoplastic fluid 6, 30, 39, 100, 101, 180, 214, 217, 218, 228, 230, 234, 250
 pseudoplasticity 5, 100, 108, 172, 219, 223, 224, 231
 pseudoplasticity index 99, 102, 116, 147, 148, 217, 218, 223, 224, 228, 232
 purely viscous fluid 79
- r**
 Rayleigh number 24, 221, 223–225, 241, 243, 244
 recoil 3
 reduced shear stress 160
 relaxation parameter 244
 relaxation time 7, 9, 23
 retardation parameter 244
 retardation time 7
 Reynolds number 8, 9, 17, 24, 50, 100, 121, 160, 166, 196, 215, 217, 218
 rheogram 207
 rheological model 5
 rheopectic 2, 4
 Runge–Kutta scheme 237
 Runge–Kutta–Gill method 199

s

- scale analysis 168, 176, 184, 227
 second invariant 7
 second-order central difference 237
 second-order fluid 70, 78, 92, 93
 secondary circulation 214
 secondary flow 222
 shape factor 166
 shear rate 1–7, 9, 78, 121, 158,
 205–207, 213, 214
 shear stress 1–10, 18, 19, 30, 43, 50, 78,
 104, 105, 111, 120–122, 132,
 145–149, 156, 157, 159–161,
 205–207, 213
 shear thinning 218
 shear viscosity 1, 227
 shear-thickening 3, 207
 shear-thickening fluid 4
 shear-thinning 207
 shear-thinning fluid 4, 17
 shear-thinning viscosity 6, 205, 207
 Sieder–Tate correction factor 215
 similarity solution 69, 91, 164
 skin friction 5
 skin friction coefficient 32, 135, 151
 smooth circular pipe 131, 141, 144,
 158
 solid-particle suspension 5
 sphere 163, 164, 166, 167
 stability 222
 stability analysis 221
 stagnant region 224
 stagnation region 78, 81, 89, 92–94,
 115, 125
 Stanton number 134, 135, 141, 149,
 151, 154–156
 starch suspension 4
 stationary instability 242
 sublayer 158
 supercritical region 225
 surfactant 5
 Sutterby fluid 6, 205, 206
 Sutterby model 6, 205–207

t

- Taylor series 22
 temperature profile 90, 170, 185, 199,
 231, 234, 237

thermal boundary layer 27, 46, 56, 74,
 76, 84, 85, 98–100, 102, 227

thermal boundary layer thickness 73

thermal boundary-layer 45, 70

thermal boundary-layer
 thickness 75

thermal layer 157

thixotropic 2, 4

thixotropic behavior 2

time scale of deformation 2, 9

tomato ketchup 4

toothpaste 4

tortuosity factor 16, 17

transient 235, 238

transient behavior 222

transient convection 238

transient thermal convection 213

turbulence 98, 101, 110, 119

turbulent boundary layer 132, 149

turbulent boundary-layer flow 137,
 138

turbulent flow 131, 135, 141, 143, 144,
 149, 154

turbulent forced convection 157

turbulent friction 5

turbulent pipe flow 131, 133

turbulent shear 132

two-phase flow 164

u

uniform heat flux 206, 209

v

velocity boundary layer 46

velocity distortion 217

velocity distribution 220

velocity model 136

velocity profile 84, 90, 149, 157, 158,
 170, 196, 199, 220, 231, 234

velocity profile distortion 219

vertical cone 63

vertical cylinder 164

vertical flat plate 29, 86, 87, 97, 100,
 109, 110, 126, 163–165, 173, 178,
 181, 183, 187, 188, 193, 201, 207,
 213, 235, 238

vertical isothermal plate 79

vertical pipe 144, 157

- vertical plate 245
vertical slender cone 63
vertical tube 146, 215–220
viscoelastic 2, 4
viscoelastic behavior 1, 3
viscoelastic fluid 6, 7, 89, 144, 157, 181, 201, 222, 225, 241
viscoelastic material 3
viscoelasticity 94, 222
viscometric flow 7
viscosity 1, 3, 4, 6, 7, 9, 19, 23, 112, 121, 131, 132, 135, 149, 150, 152, 158, 181–183, 188, 201, 202, 220, 221, 223–225
viscous 98, 99, 112, 113
viscous behavior 2, 3
viscous boundary-layer 30
viscous effect 18
viscous fluid 213, 222
viscous material 2
viscous shear 132
viscous stress 15
viscous sublayer 134, 150
von Karman constant 132, 149
- w**
wave number 242
wavy surface 244, 245
wavy vertical plate 245
wedge 29
wedge angle 34
wedge flow 137, 153
wedge half angle 32
Weissenberg number 75, 80, 81, 182
wet sand 4
- y**
yield stress 1–4, 6, 164, 213, 227–229, 238, 240, 241
- z**
zero shear 221
zero shear rate 6, 207
zero shear viscosity 206