

Index

a

- A, B and C, *see* continuum elasticity
- α , thermal expansion 32, 35, 98
- anelasticity 324
- attenuation 167
 - energy extraction 168
 - linear 168
 - how to measure Q 172
 - why measure Q 171
 - measurements of 324
 - nonlinear 170, 175
 - how to measure Q 174
 - it's the amplitude baby 175
 - measurements in lead alloy 325
 - wavevector dispersion 168
- auxiliary fields 158, 236
 - in nonlinear nondestructive evaluation 324, 336
 - saturation 237
 - temperature 242

b

- backbone of hysteresis loop 138, 143
- Biot theory 240, 267
- brick and mortar 1, 95, 228–229

c

- C-scan 354
 - experimental example 355
- CFA 178, 285, 291
 - a resonance where there is none 195–197
 - Berea sandstone, results 286
 - example, constant strain curve 183, 292–293
 - finding physical fields 193, 293
 - granite, results 292–296, 298
 - in/out of phase amplitudes 182, 193

- steps in analysis 182–184
- virtues 185
- chemical potential 102, 238
- chemical potential protocol 105–106, 240
- c_{ijkl} 29, 210
- continuum elasticity 29
 - A, B and C 41–47
 - dynamics 31, 41–47
 - linear 29, 44
 - nonlinear 30, 45–47
 - A, B and C 30, 272
- crack 75
 - as mechanical diode 327
 - clapping 328
 - crack model
 - Hooke's law 329
 - harmonic generation 330
 - spring model 327–328
 - stick-slip behavior 328
 - wave modulation 330

d

- dislocations 324–325
 - Granato–Lücke theory 324
- DMG model 153–154
 - frequency shift 156, 158
 - Preisach space 153
 - shift in Q 156
- DORT 218, 225
- dynamic-dynamic 267
 - fast dynamics 275
 - resonant bar 274
 - earth 316
 - slow dynamics 274
 - wave mixing 268
 - collinear 270
 - collinear, parametric array 272–273
 - collinear, scaling with x , A^2 , k^2 270–271

- KZK equation 274
 - noncollinear 268
 - noncollinear, geometry 269
 - Northridge earthquake 318
 - parametric array 313–314
- dynamic-dynamic process 40

e

- effective medium theory 76
- central dogma 78–79, 82
 - examples 83
 - FDEE 114
 - Hertzian contact scaling 87
 - Hertzian contacts 83
 - in parallel 85
 - in series 85
 - van der Waals surfaces 87
 - bookkeeping 90
 - Preisach space 90
- elastic state dynamics 153–157
- endpoint memory 120
- energy landscape 155, 209

f

- fast dynamics 6, 145, 274–277
- anomalous 308
 - linear 145
 - nonlinear 275
- FDEE scaling 128, 285, 295, 301, 310
- field experiments 313
- active probes 313
 - resonant bar 315
 - wave mixing 313
 - passive probes 318
 - Northridge earthquake 318
- form factor
- \mathcal{F} 201
 - $\mathcal{G}, L + T \rightarrow T$ 52
 - for $\delta c_{ijkl}(\mathbf{x})$ 207
 - $H(R)$ 62
 - normal modes 58

g

- Green function 64–66
- free space 64
 - resonant bar 65

h

- Hermitian matrix 214, 225
- Hertz–Mindlin contacts 70, 301
- EMT 83
 - fcc lattice 138
 - scaling of c and β 301
- homodyne 177

hysteresis 137

- observation in aluminum single crystal 324, 339
- endochronic model 136, 141
- FDEE 136
- fluid configurations 104–105
- Hertz–Mindlin contacts 136–138
- k – Σ 121
- loop 121
 - due to temperature 246
 - time evolution 237, 246
- Masing rule 136, 139
- strain 4
- van der Waals material 92–93

i

- invasion percolation 239–240

j

- Jones and Kobett 53–54, 268

k

- Kaiser effect 232

l

- Lennard–Jones interaction 15, 19
- log time 4, 6, 162, 286, 297, 308, 310, 324
- resonant bar
 - threshold 295
- lumped element model 123, 173, 176

m

materials

- Agar gelatin 264
- alluvium 320
- aluminium powder 1
- Berea 229–231, 233
- cement 3
- ceramic 3
- earth–Northridge 319
- glass beads 270, 301–304
- granite 262–263, 292
- limestone 270
- sandstone 2
 - Berea 178–179, 229, 231, 233, 248, 270
 - Berea and T 244
 - Castlegate 231, 234
 - Fontaineblau 231
 - Fontainebleau and neutrons 231
 - Meule, P and S_w 266–267
- sandstones, TBC 257
- Sierra White granite 270
- soil 3, 231, 236

- TBC 2, 231, 235
- various 310
- mesoscopic elastic elements 69, 113
 - cracks 75, 328
 - FDEE
 - resonant bar 123
 - resonant bar, frequency shift 127–129
 - resonant bar, scaling 130
 - resonant bar, shift in Q 127–129
 - rules for behavior 116
 - wave mixing 130
 - wave mixing, (f_1, f_2) 131
 - wave mixing, (f_1, f_2) and phase portrait 132–135
 - frictional 137
 - frictional contact 122
 - Hertz–Mindlin contact 70–71, 121, 137
 - Hertzian asperities 72–73, 122
 - hysteretic Hertz–Mindlin contact 72
 - van der Waals surfaces 73–74, 121
- MG model 113–115, 138–143, 153
- modulus 233
 - dynamic 233
 - dynamic component 254–257
 - granite 262
 - hysteretic component 254–257
 - one way 233, 238
 - P and S_w 266
 - two way 233, 238
- n**
- NESS 277
 - threshold 277, 298
- neutron scattering
 - internal stress 100
 - internal/external strain gauge 230–232
- nondestructive evaluation 323
 - harmonics 327
 - measurement of harmonics 337–338
- nonlinear elastic wave spectroscopy (NEWS) 327
 - imaging of nonlinear scatterers 353
 - harmonic imaging 353, 355
 - imaging applying time reversal nonlinear elastic wave spectroscopy (TR NEWS) 357, 359, 361
 - modulation imaging 354, 358
 - measurement of progressive fatigue 336, 347, 349
 - experimental example 350–352
- nonlinear nondestructive evaluation
 - history 324
- nonlinear parameters 263
 - A , B , and C 263
 - β 264
- nonlinear ringdown spectroscopy (NRS) 341
 - experimental example 344
- nonlinear ultrasound resonant spectroscopy (NRUS) 341
 - experimental example 343
 - resonant bar 341
- Nonlinear Wave Modulation Spectroscopy (NWMS)
 - experimental configuration 334
 - in cracked plexiglas 333
- nonlinear wave modulation spectroscopy (NWMS) 330
 - experimental configuration 332
 - experimental example 331, 340
 - impact plus pure tone 337, 342
 - in cracked metal 334
 - in cracked steel 331
 - summation average 339
- p**
- peak bending 4, 57, 128, 178
- perturbation treatment
 - Luxemburg–Gorky 59
 - resonant bar
 - FDEE 131
 - $L + L + L \rightarrow L$ 55
 - selection rules 53
 - t independent PT
 - NL normal mode tomography 220
 - normal-mode tomography 203
 - time of flight tomography 202
 - time reversal 209, 211–215, 218, 223
 - wave mixing
 - $L + L \rightarrow L$ 49
 - $L + T \rightarrow T$ and $T + T \rightarrow L$ 51
- phonon picture 13
 - anharmonic 18, 324
 - continuum limit 24
 - elastic constants 27
 - elastic constants, numerical 27
 - wave equations 28
 - harmonic 16
 - normal modes 17
 - perturbation theory 16
 - 3-phonon process 18, 40, 53–54, 133, 269
 - 4-phonon process 53, 201
 - second-order process 53
- photomicrographs
 - cracked, sintered metal 335

- pore space 104
 - epoxy 229–230
- Preisach space 118–119
 - density 249
 - FDEE 116
 - for fluid configurations 239
 - inversion 122–124, 247
 - saturation 250
 - two component, many component 252
 - uniform density approximation 117, 125, 254
 - van der Waals surfaces 91
- probe 300, 310
 - in slow dynamics 276
 - Luxemburg–Gorky 59–64, 201
 - NESS 295, 298
- pump 300, 310
 - in slow dynamics 276
 - Luxemburg–Gorky 59–64, 201
 - NESS 295, 298
- q**
- Q*, *see* attenuation
- quasiharmonic approximation 20
 - dT 22
 - dV 21
 - dV^2dT , Luxemburg–Gorky 22, 59
 - $dVdT$ 21
 - dW , an auxiliary field 21
 - numerical estimates 24
- quasistatic measurements 227
- quasistatic process 40
- quasistatic/dynamic measurements 261
 - pressure/dynamic 261
 - *A*, *B* and *C* 262
 - saturation/dynamic 265
 - temperature/dynamic 264
- quasistatic/dynamic process 40, 46
- r**
- ratchet 159, 277
- rearrangement 232
- reciprocity 213, 224
- relaxation rates 152
 - broad spectrum 149–153
- resonance
 - observations in materials containing dislocations 325
- resonant bar 55, 57, 177–178
 - CFA analysis 180–186
 - frequency shift 179
 - lumped element model 123, 176
 - modulation in aluminum 327
 - NESS and generic behavior 278–279
 - shift in Q 179
 - synthetic data 181–182, 188–189
 - CFA analysis 184–185
 - temperature
 - resonance frequency *by ear* 244
- resonant bar slow dynamics AF 276
- resonant bar slow dynamics IF 276
 - case study, glass beads 301
 - constant strain measurement 291
 - defined 276–280
 - elastic state and NESS 279
 - $\log(t)$ 286, 297–299, 308–310
 - low strain behavior 289–290
 - elastic state and sweep rate 282–283, 285
 - elastic state time evolution 279
 - frequency protocols 280–281, 289, 296
 - thumper 315
 - frequency shift
 - earth 315
 - earth-Northridge 320
 - non-rock-like materials 305
 - rocklike materials 304
 - $\log(t)$ 288, 295, 317
 - low strain behavior 290
 - NESS
 - defined 280
 - threshold 299
 - Q^{-1} shift
 - non-rock-like materials 306
 - resonance curves
 - various materials 307
 - two mode experiment 298, 300–301
- resonant ultrasound spectroscopy, RUS 200
- RTMF 186
 - finding physical fields 187
 - scaling of f and Q^{-1} 193–194
 - steps in analysis 186–189, 191
- s**
- saturation 6, 159
 - chemical potential 102–108, 241
 - coupling to strain 32, 106, 239
 - internal forces 241
 - low saturation/tensile forces 239
 - effect on Preisach space 242
 - fluid configurations 104–108, 239
 - internal forces 108–111
- saturation stays in 239
- selection rules 53, 268
- slow dynamics 6, 145–146, 158, 309
 - AC drive 161

- in nondestructive evaluation 345
- linear 145, 152
- *quasistatic* hysteresis loops 235
- temperature 162, 164, 244, 245
- slow dynamics diagnostics (SDD)
 - experimental example 348
 - slope amplifier 345
 - slow dynamics 345
- sound velocity 4
 - $c_L(P)$ 4, 262
 - c_L 45
 - $c_L(P)$ 46, 229
 - c_T 45
 - numerical estimate 17
- spectroscopy 199
 - linear 199
 - nonlinear 200, 204
 - $A(f)$ 200
 - $A(t)$ 200
 - homogeneous 200
 - inhomogeneous 202
- strain stays in 233
- stress protocol 117–119, 156
 - elaborate 250–253
 - quasi-static 248
 - strain response to AC stress 150–151
 - strain response to transient stress 148
- t**
- temperature 6, 61, 97, 162
 - equation of motion 59, 168
 - hysteresis loop
 - asymmetry 247
 - slow dynamics 247
 - internal forces 101–102, 243
- temperature protocol 164, 243
 - temperature chirp 244–245
- tile model 78, 97
 - brick and mortar 95, 103
 - effective medium theory 78
 - Hertz tile 83
 - nonuniform 77
 - notation 98, 103–104
 - saturation 102
 - percolation 110
 - saturation strain coupling 102
 - temperature 97
 - temperature strain coupling 98
 - tile space 80
 - uniform 76
 - van der Waals tile 87
- time reversal 209
 - linear 209
 - amplitude training 215
 - experimental protocol 213
 - transfer matrix 213
 - mirrors 211
 - nonlinear 223
 - amplitude training 225
 - experimental protocol 224
 - imaging of nonlinear scatterers 357
 - time-reversal matrix 225
 - transfer matrix 224
 - time-reversal matrix 213
- time-reversal
 - linear
 - amplitude evolution 217
 - amplitudes 216
 - mirror/scatterer geometry 212
- time reversal nonlinear elastic wave spectroscopy (TR NEWS)
 - impulse response 363
 - isolating mines 362
 - phase inversion method 361
 - experimental example 364
 - variable amplitude/scaling subtraction method 364
- tomography 199, 202, 206
 - linear
 - normal mode 203
 - normal mode, frequency shifts 208, 210
 - normal mode, numerical example 206
 - time of flight 202
 - nonlinear
 - normal mode 220
 - time of flight 218
- traditional theory of NL elasticity 39
 - dynamic response 47
 - β and γ 48
 - linear 44
 - Luxemburg–Gorky 59
 - quasistatic response 41
 - quasistatic/dynamic response
 - $c_L(P)$ 46
 - resonant bar 55
 - $L + L + L \rightarrow L$ 55
 - why not $L + L \rightarrow L$? 56
 - wave propagation 48
 - $f + f \rightarrow 2f$ 51
 - higher-order processes 52–53
 - $L + L \rightarrow L$ 48
 - $T + T \rightarrow L$ and $L + T \rightarrow T$ 51
 - $u^{(2)} \propto x$ 51
- x**
- X, the conditioning field 112, 145, 158–159