Cambridge University Press 978-0-521-18799-2 - Granular Physics Anita Mehta Index <u>More information</u>

Index

acceleration amplitude, 7, 10 accommodation function, 196, 199 activation energies, 95-96 Aeolian sand ripples, 168-174 aftermath piles, 121-125 ageing anomalous, 163 shape-dependent, 99-100, 102-103 amplification, 134, 138, 146 amplitude cycling, 90-93 amplitude equations, 207 angle of maximal stability, 12, 63, 69, 171, 174 angle of repose athermal requirement for, 52, 63 Bagnold angle and, 17, 65-66 crossover length and, 131 formation history dependence, 12, 66, 74 pressure profiles and, 248-249 ripples, 170, 174 roughness and, 74, 130-131 sandpile bistability and collapse, 63-71 SOC model and, 115-116 angoricity, 3-4, 215 anisotropic elasticity, 267 annealed cooling, 97-100 annealed disorder, 119 annealed values, Edwards' flatness, 111 anomalous ageing, 163 anomalous roughening, 74-75, 165-168 anticorrelations, 36, 40, 106, 108-109, 112 apertures, flow through, 4-5 apparent mass, overloaded silos, 246-248, 271 'arching', 245 asymptotic density, 86-87, 92, 111 asymptotic packing fraction, 96-97 asymptotic roughness, 119-129 asymptotic smoothing, 149, 162-163, 165, 167 athermal system consequences, 19, 52, 63 autocorrelation function, 31, 33 avalanche footprints, 72-78 triangular avalanches, 71-78 uphill avalanches, 71-78, 121, 124 avalanche models

cellular automaton models, 14-15, 116-120 coupled continuum equations, 148-167 coupled map lattice model, 133-147 directed percolation model, 70 self-organised criticality and, 12-13, 115-116 avalanche size distribution, 14-15, 120-124, 126-127, 137-143 Type I and Type II, 115–120 avalanches angle of repose and, 1, 63, 72 bistability of sandpiles and, 1, 69-75 intermittent and continuous, 148-150, 156, 163, 167 large avalanche surface effects, 118-131, 142 long duration and continuous, 149-150, 156-162 mass time series, 122-124 percolative transport and, 39, 70 in rotating cylinders, 132-135 snow and rock, 115, 148 system-spanning, 128 Bagnold angle, 17, 63, 65-66, 69 Bagnold number, 2, 176 barrier-height-to-temperature ratio, 67 base extension, bridges, 55, 58 BCRE (Bouchaud, Cates, Ravi Prakash, and Edwards) model, 157, 166 Bennett model, 20 Bessell functions, 231, 266 biaxial tests, 273 bistability angle of repose and, 1, 12, 66 in ripples, 171, 174 in sandpiles, 63, 65-66 in tilted sandpiles, 69-78 blocked configurations, 83, 85 Boltzmann equations applicability to granular gases, 177-178, 184-185, 188. 196-197 applicability to the jammed state, 209, 212-213 Born-Huang formula, 253, 256 boundary conditions, 196-200, 207, 266, 269

Cambridge University Press 978-0-521-18799-2 - Granular Physics Anita Mehta Index More information

298

Index

boundary layers avalanche motion and, 13, 147, 163 fast dynamics within, 107 grain-inertia simulations, 23 ordering depth and, 101, 113 boundary stress, 258 branch vectors, 256, 258 'Brazil nut' phenomenon, 47-50 bridge formation, 30, 38, 52-62 bridges characteristic descriptors, 55 collapse and grain anticorrelation, 36, 40, 107 defined, 53 linear, 53-56, 58-61 shape and vibrational intensity, 30 Brownian motion, 2, 6-7, 52-53, 67-68 Burgers' equation, 16 Burnett equations, 183, 187, 189, 195 Burnett order, 182-183, 195, 200, 204 CA models, see cellular automaton models Cahn-Hilliard model, 206 captors, stress, 257 carbon paper technique, 237-238 cascade reorientation, 86-90 Case A model, rotating cylinders, 151-156 Case B model, rotating cylinders, 156-162 Case C model, rotating cylinders, 162-167 CE expansion, see Chapman-Enskog expansion cellular automaton (CA) models, 5, 13-15 grain-inertia regime, 23 with long-range interactions, 105-106 nonequilibrium regimes, 102-103 with orientational rearrangement, 94-96, 118-119 ripples and dunes, 168 sandpile collapse and, 70-78, 94-96, 118-131 self-organised criticality and, 11-13, 116-117 Type I avalanches, 116-117 Type II avalanches, 118-131 channels, flow through, 4-5, 23 Chapman-Enskog (CE) expansion, 185-189, 202, 204, 206, 208 limitations of, 177, 182, 197 chute flows, 208 cluster aggregation model, 112-113 cluster reorganisation, 28, 70 clustering as a hydrodynamic effect, 178-181 clusters coupling with mobile grains, 148 deformation and shaking intensity, 43 instability and continuous avalanching, 161-162 intercluster and intracluster relaxation, 169, 174 merger as 'coarsening', 178, 180 as 'stuck' grains, 151 CML (coupled map lattice) model, 15, 118, 134-141, 143-146 coarse-graining effective medium theory, 259-261 microscopic theory of, 226-230 stress field data, 253-261

coarse-graining function, 253 'coarsening' process, 107, 178, 180 coefficients of restitution, 22, 181, 184-185 cohesion and segregation, 51 collapse mechanisms, 181-182, see also bridges; sandpiles collision forces, see Bagnold number collision laws, granular gases, 184, 196-197 colloids, 16, 97, 112, 229-230 column grain size, 137 column models, see also lattice-based models ideal height, 133 jamming and, 104-105, 110-111, 113-114 compaction bridge collapse and, 53 irreversible and reversible branches, 90-92, 97 - 100logarithmic compaction, 84, 86-87, 93, 99, 103 modelling, near the jamming limit, 79-93 tapping and the compaction curve, 83-84 compactivity, 3-4 density fluctuations and, 64-65 shaken sand in cylinders, 210, 214-215, 220-221, 222-223 vibrated beds, 6 complex bridges, 53-54, 56 computer simulations, see simulations conductivity of graphite, 211 configurational entropy, 3, 111-112 configurational memory, 140, 146-147 configurational overlap function, 98-100 connected correlation function, 102-103 conservation of momentum, 201 consolidation after avalanching, 125 by tapping, 40 CML model and, 133, 135-138, 140 isostatic behaviour and, 230 Monte Carlo consolidation, 26, 28-29 contact angles, 36, 234, 240, 261 contact forces coarse-graining, 253-261 contact angles and, 234, 240, 261 deriving stresses from, 253-259 determination of, 209 effective medium theory, 259-261 exponential distribution of, 232, 242, 245 contact networks, 218 contact orientation in layers, 240-242 continuous avalanching, 149-150, 156-162 continuum approach avalanches in rotating cylinders, 133-135 Boltzmann equations and, 187 bridge formation, 57 coupled continuum equations, 148-175 friction effects and, 203 ripples and dunes, 168, 171, 174 convection processes, 5-11, 50-51 cooperative dynamics, 27-28, 36, 38, see also angle of

repose; bridge formation

Cambridge University Press 978-0-521-18799-2 - Granular Physics Anita Mehta Index More information

Index

coordination numbers, 20-22 bridge formation and, 55 isostatic equilibrium and, 216, 222, 230 random graph models, 80 shaken granular systems, 212, 222 vibrational intensity and, 29-31 volume fraction and, 33 correlation, molecular gas kinetics, 184-185 correlation functions autocorrelation function, 31, 33 cluster aggregation model, 112 connected, 102-103 coupled continuum equations, 152 EW model, 152-154 height-height correlation function, 120, 128, 150, 153 mass-mass correlation function, 127-128 random packings and, 33-36 transverse and longitudinal, 35 two-time, 102-103, 163 zero-temperature dynamics, 108 Cosserat elasticity, 267 Couette flow, 23, 51, 179, 237 Coulomb friction, 201, 203, 236, 270 coupled continuum equations, 148-175 coupled map lattice (CML) model, 15, 118, 134-141, 143-146 critical aspect ratios, 126 critical phenomena self-organised criticality, 11-13, 115-116 size dependence, 140 critical slope threshold, 72, 137 crossover behaviour diffusive to asymptotic smoothing, 161-162 roughening to asymptotic smoothing, 165-166 crystalline limit, 98 crystallisation, 44-46, 90 curve fitting, 41, 220 cylinders, see rotating cylinders; shaken cylinders damping, 13, 15, 107 degrees of freedom fast and slow, 79 quadrons and, 220-221 translational and spin, 202, 205 density, see also packing densities asymptotic density, 86-87, 92, 111 of shaken systems, 211 density fluctuations angle of repose and, 63-66 bridges and, 59 clustering theory and, 178-180 compaction near the jamming limit, 84, 87 kinetic energy density, 186 variation with time, 155-156 zero-temperature dynamics and, 106-108 density of states, 220 diffusive behaviour crossover to asymptotic, 161-162 linear bridges, 60 ripples, 170

299

self-diffusion, 42-44 shaking intensity and, 42 dilatancy angle of repose and, 63-66, 69 dynamic representations, 17 excess volume and, 146 large avalanches and, 139 roughness and, 74 sandpile collapse and, 69, 74 dilatancy waves, 4-5 dilation phase, 25-27, 54, 86 quench phase and, 82-84 directed percolation model, 70, 77-78 discretisation, continuum equations, 157-158 disorder cellular automaton models and, 14 compaction of disordered grains, 79-93 evolution of, 139 displacement correlations, 34 dissipation coefficient, 135 distinct element method, 24 distribution functions, see equilibrium; event-size; force; single-particle; spin distributions divergences, infrared, 157-158, 167 dome formation, 58-61 double Fourier transforms Edwards-Wilkinson equation with flow, 152-154 temporal and spatial roughness, 150-151, 158-160 tilt combined with flowing grains, 164-165 DSMC (direct simulation Monte Carlo) simulations, 188 dunes, 167-168, 175 dynamical arrest, 79 dynamical exponent, 150 dynamical heterogeneities, 34 dynamical phase transitions, 86-87, 97 dynamical scaling, 119-120 dynamics, see fast dynamics; slow dynamics earthquakes, 124, 135, 142, 147 Eden model, 19 Edwards' compactivity, see compactivity Edwards' hypothesis, 108-113 Edwards' singularity, see infrared divergence Edwards-Wilkinson (EW) equation, 151-156 effective medium theory, 253, 259-261, 264 effective temperature, 2, 5, 17, 65, 67, see also granular temperature effective viscosity, 22-23 elasticity, see also inelasticity Cosserat elasticity, 267 effective medium theory, 259-261 isostaticity and, 230 stress field computation using, 264-268 elasto-plasticity, 233, 253, 259, 261-262, 273 elongated grains, 5 energy activation energies, 95-96 external sources, 24-25 energy sink term, 203-204 Enskog–Boltzmann equation, 184, 200

Cambridge University Press 978-0-521-18799-2 - Granular Physics Anita Mehta Index More information

300

Index

Enskog correction, 194, 206 Enskog equations, 200, 206, see also Chapman-Enskog (CE) expansion entropy configurational entropy, 3, 111-112 Edwards' hypothesis and, 108-113 force probability distribution and, 245 ground-state entropy, 106 shaken sand in cylinders, 210, 214, 228 equilibration times Boltzmann solutions and, 183 dynamic transitions and, 86 for jamming, 92 number of particle collisions, 196-197 shaken sandpiles, 100-101 equilibrium distribution functions, 191 equipartition in granular gases, 207-208 equivalent temperatures, see compactivity ergodicity breakdowns, 87 Euler angles, 217 Euler equations, 187 Euler relations, 221, 227, 287 event-driven simulations, see hard-particle simulations event size distributions, 126, 137-143 EW (Edwards-Wilkinson) equation, 151-156 excess volume, see dilatancy excitations, 113, 220 excitons, 68 exit mass sizes, 126-127, 141-142, 145 fabric tensors, 217 fast and slow degrees of freedom, 40-42, 63-64 fast dynamics non-ergodicity and, 87, 97 simple CA model, 94-96 SPRT and, 84-86 FCC (face centred cubic) packing, 251 Fibonacci numbers, 114 flipping mechanisms, 83, 89, 95, 119 flowing grains Case B model, 156-162 Case C model, 162-167 coupling with clusters, 148, 174 diffusion in ripples, 170, 172 EW model, 151-156 molecular dynamics approaches, 22-24 through wedges, channels and apertures, 4-5 fluid mechanics and jamming, 209 fluidisation, 6, 8, 45, 176-178 fluidised regime characteristics, 99 flux-divergence term, 170 force and torque balance, 216-217, 223, 226-227, 230, 234–235 force chains, 57, 229, 236, 272 force distribution function, 238-239, 243-244 forces, see also contact forces contact orientation and, 240-242 large-scale treatment of distributions, 245-273 microscopic treatment of distributions, 233-245 probability distribution, 237-239, 241, 245, 273 sandpile force transmission, 216

spatial distribution, 230-232 volume fractions and, 215-222 formation history, see preparation history Fourier transforms, see double Fourier transforms; single Fourier transforms 'Fredholm alternative', 191, 197 friction bridge formation and, 30, 54 convective motion and, 9 force chains and, 230 force probability distribution and, 237 in granular gases, 200-206, 208 in silos, 247-248 in vibrated beds, 6-7 intergrain friction, 4 internal friction coefficient and angle, 268 response profiles and, 252 friction coefficients, 4, 23, 201 granular statics, 234, 237-238, 247, 252, 268, 270 frozen state, 98, 100-102 frustration, 81-84, 91, 106, 228-229 full structure factor, 150 Gamma distributions, 244 gases and granular media characteristics, 18, see also granular gas models geometric tensors, 218-219, 228 glaciers, 168 glasses displacement correlations, 34 jamming behaviour exhibited by, 52, 92 Lenard-Jones glasses, 261 percolative transport, 39 'glassy' dynamics, 98, 100-102 golden mean, 114 Grad expansion, 184, 187-188 grain anticorrelations, 36, 40, 108-109 grain inertia amplification and, 134, 138 cellular automata models, 13-15, 116 CML models, 137-140, 146-147 grain-inertia regimes, 2-4, 22-23 grain reorientation avalanches with, 115-131 cluster reorganisation and, 70 intracluster rearrangement, 137 stress-strain curves, 263 grain shapes aspect ratio, disordered sandpiles, 125, 127 ground state retrievability and, 114 non-spherical grains, 208 orientation modes and, 102-103 packing simulations, 19, 49 zero-temperature dynamics and, 106-108 grains, see also flowing grains contacts between rigid grains, 230, 234 weight, in q-model, 243 granular gas models, 176-208 boundary conditions, 196-200 friction effects, 200-206

kinetic theory, 184-196

Cambridge University Press 978-0-521-18799-2 - Granular Physics Anita Mehta Index More information

Index

granular temperature, 177 as a hydrodynamic field, 201 compactivity and, 3, 64 rapid shear regimes and, 3, 22, 177-178 vibrated beds, 6 graphite, density and conductivity, 211 gravity bridge formation and, 54-55 granular gases in outer space, 208 packing simulations and, 19, 24 Green function, 229 Green-Kubo relations, 206-207 ground states entropy, 106 excitons, 68 metastability, 179 propagation, 107 retrievability, 114 zero-temperature dynamics, 106-107, 110 hard-particle simulations, 22-24, 28 of the jammed state, 209 simple CA lattice model and, 98 HCP (hexagonal close packed) packing, 237-238, 251 HCS (homogeneous cooling state), 178-180, 187, 200, 204-205, 207 heap formation, vibrated beds, 7 heat flux, 183, 187, 192-194, 203-204, 206 Heaviside functions, 35, 256, 258 height-height correlation function, 120, 128, 150, 153 history, see preparation history hole radius distribution, 39 homogeneous cooling state (HCS), 178-180, 187, 200, 204-205, 207 homogenisation, see coarse-graining hoppers, 4-5, 23, 58, 60 hopping between potential wells, 43-44 hopping grains in ripples, 169-171 hourglasses, 4-5 hydrodynamic regimes, 42-44 clustering in granular gases, 178-183 frictional granular hydrodynamics, 200, 202-208 kinetic theory and, 185-188, 190-191, 195, 197 hyperbolic equations, 229, 267, 269-273 hypergraphs, 79-80 hysteresis in granular media, 21, 200, 263 in sandpiles, 2, 63, 98 in tilted sandpiles, 73-74 ideal height, column models, 133 impurities (tracer particles), 9-10, 47-49 inelasticity, 181-182, 195 Boltzmann applicability and, 177, 184, 199 inertia, see grain inertia; particle inertia infrared divergence, 157-158, 167 inhomogeneous relaxation, 96 integrodifferential equations, 196-197

301

intermediate phase, 99 intermittency, surface layer, 113-114 intermittent avalanching, 149-150, 156, 163 internal friction coefficient and angle, 268 interparticle percolation, 9-10 intrinsic size dependence, 140 irreducible loops, 230 irreversible branch, compaction curve, 90-92, 97-100 irreversible packing and plasticity, 262-264 isostaticity coordination numbers and, 216, 222, 230-231 force chains, 229 polydisperse beads, 235 jammed systems Boltzmann applicability, 209, 212-213 bridge formation and, 52, 57 configurational probabilities and, 110 contact network loops and voids, 218 grain anticorrelation and, 36 thermodynamics of, 209-232 vibrated hourglasses, 4-5 jamming limit amplitude cycling model, 90-92 displacement correlations and, 34 entropies near, 111 modelling compaction near, 79-93 shaken sand and grain shapes, 104-114 Janssen's model for silos, 233, 246-248, 270-271 Kadanoff model, 144 kernel function, 213 kinetic theory, 183-196 Knudsen domains, 208 Knudsen number, 185-188, 196, 204 Knudsen orders, 195 KPZ (Kardar-Parisi-Zhang) equation, 16 Landau-Ginsberg models, 206-207 Landau's notation 264 large-scale properties of granular materials, 245-273 lattice-based models, 13, 23, 79, 85, 104, see also CA models; CML model; column models lattice gas models, 116 lattice grain models, 13-14, 116 least squares fit, 40, 42, see also curve fitting Lenard-Jones glasses, 261 linear bridges dome formation from, 58-61 formation, 53-54 size distribution, 55-56 link angle, bridge formation, 58 liquids, granular media compared to, 1, 18 logarithmic coarsening law, 107 logarithmic compaction, 84, 86-87, 93, 99, 103 logarithmic growth of packing fraction, 97 longitudinal correlation functions, 35 loops, 54, 80, 218-221, 226-227, 230 Love stress tensor, 217 low-amplitude pinning, 91 low-temperature dynamics, 113-114

intergrain friction, 4

Cambridge University Press 978-0-521-18799-2 - Granular Physics Anita Mehta Index More information

302

Index

magnetic resonance imaging (MRI), 50-51 magnitude distributions, see avalanche size distributions main axis, bridges, 55 mass-mass correlation function, 127-128 maximal angle of stability, 12, 63, 69, 171, 174 'Maxwell demon effect', 180 MD (molecular dynamics) simulations, 22-25, 30, 55, 57 mean angle, 58-61, 72, 125 mean-field equations, 166-167, 244 mean-field theory, 79-81, 112 mean force, 240 mean free path, 177, 182-185, 187-188, 196-198, 204 mean free time, 183 mechanical equilibrium, 210, 230, 264, 269, 273 coordination number and, 216 mesoscopicity, 182 metastability dense granular systems, 179 equilibration of older systems, 99 finite lattice and mean field, 112 three-spin model requirement, 81-82 minimum event size, 134 miscibility theory, 215 mixtures of grains, see segregation of mixtures mobile grain coupling with clusters, 148 Mohr-Coulomb yield criteria, 233, 268-272 molecular chaos (Stosszahlansatz), 184, 212 molecular dynamics (MD) simulations, 22-25, 30, 55, 57 molecular gases, 176-177, 184, 186-187, 195 monodisperse spheres Boltzmann equation, 185 simulations based on, 19, 21, 39 Monte Carlo simulations, 18-22 compression phase, 28 DSMC simulations, 188 friction and, 54 size segregation, 10, 25 three-spin model and, 82 mutual stabilisation, 53, 55 Navier-Stokes equations, 116, 182, 187, 189, 195 Newton's third law, 217, 226, 254 NMR (nuclear magnetic resonance), 51, 58 noise, 25, 88-89, 113, 151, 173 white, 59, 64, 157, 162 non-Abelian models, 20-22, 116 non-equipartition, 207 non-ergodicity, fast dynamics, 87, 97 non-hydrodynamic phenomena, 181-182, 207 nonsequential packing simulations, 20-22, 28 nucleation scenarios, 45 one-species model, 168 ordering length, 113-114 orientation angle, 55, 58, 217 orientation distribution, 36-37, 240 oriented stress linearity (OSL) model, 271-273 orientedness parameter, 100-102

orthogonality principle, 42, 191-193 oscillons, 8 OSL (oriented stress linearity) model, 271-273 Oslo rice pile experiments, 127 overlap function, 98-100 overshoot effect inhomogeneous relaxation and, 96-97 in silos, 247-248, 271 packing density and, 85, 263 packing densities, 3, 21, 30-31, 36, 271, see also random close packing packing fractions annealed cooling and, 97-100 bridge formation and, 61-62 disordered sandpiles, 125 monodisperse spheres, 19, 21 orientedness parameter and, 100 RCP threshold and, 44-46 shaken sand simulations, 25, 96-97 packing structures, 19-22 parking-lot' model, 89 partial voids, 39 particle inertia, 15 particle size, see grain shape; segregation of mixtures Peclet numbers, 4 percolation directed percolation model of avalanching, 70, 77-78 interparticle percolation, 9-10 segregation of mixtures and, 46-48, 51 percolation clusters, 57 percolative transport, 39 perfect packing, 45-46 'phase diagram' avalanche morphologies, 71, 77 dynamical phase transitions, 86-87, 97 photoelasticity, 236, 250-251 pinning, low-amplitude mechanical, 91-92 plasticity elasto-plasticity, 233, 253, 259, 261-262, 273 irreversible packing as, 264 onset of, 226 stress-strain curve, 268 plug flow, 5-6, 179-180 Poisson ratio, 260, 262, 265, 267, 271 polar histograms, 241-242 polydispersity granular gases, 208 response function and, 251-252 statics of polydisperse grains, 234-235, 264, 273 polymers and bridge models, 56, 60 polynomials, Sonine, 191 pore spaces, 39 pouring Maxwell demon effect, 180 preparation history effects, 12, 19-20 sandpile preparation by, 209, 246-248 simulation of, 40

size segregation and, 50

Cambridge University Press 978-0-521-18799-2 - Granular Physics Anita Mehta Index More information

> power law behaviour avalanche size distribution, 115, 129, 137, 139 density of states, 220 Fourier transforms, 159, 161, 163 q-mode force distribution, 245 power spectrum fluctuations, 88-89, 115-116 precursor piles, 121-124 preparation history angle of repose dependence on, 12, 66, 74 contact orientation and, 241-242 force probability distribution and, 237 packing density dependence on, 19, 271 pressure in jammed systems and, 209-210, 216, 248-252 stress-strain curves, 263 pressure force distribution function and, 238-239 localised overloads and, 250-252 preparation history and, 209-210, 248-250 q-model, 242-245 quadrons, 219-223, 227 quasiperiodicity, 121, 140, 146 quasistatic flow, 3-5, 23-24, 42-43, 137 quench phase, 55, 82-85 quenched disorder, 17, 92 quenched systems coarse-graining in, 226-230 stress tensor derivation for, 223 quenched values, Edwards' flatness, 111 ramp rates, 90-92, 98 random close packing (RCP) density, 19, 27, 44 dynamic transitions and, 87 jamming limit entropies near, 111 ramp rates and, 90-93, 98 random deposition in sandpiles, 141-142 random graph models, 79-93 cluster aggregation model and, 112 Edwards' hypothesis, 113 three-spin model, 81-82 random transmission coefficients, 243

random trapping, 67 random walks, 5, 42, 56, 60, 109 'rattlers', 84-86, 106-107, 110-111, 212 RCP, see random close packing density relaxation events avalanches in rotating cylinders, 133-137, 141-142, 144-145 inhomogeneous relaxation, 96 ripple formation, 169 vibrated powders, 40-41 reptating, see hopping response functions, 246, 250-252, 264, 268 response theory, 177 'reverse Brazil nut' effect, 50 reversibility density curve of shaken grains, 211, 215, 230 irreversibility for sandpiles, 223

reversible branch, compaction curve, 90–92, 97–100

Index

Reynolds dilatancy, see dilatancy rheology, 263 rice pile experiments, 127 ripple formation, 168-174 rotating cylinders avalanches in, 132-146, 149-150 Case A model, 151-156 Case B model, 156-162 Case C model, 162-167 roughness anomalous roughening, 74-75, 165-168 asymptotic roughness, 119-129 entropic landscape, 108-113 ripple formation and, 171, 174 sand in rotating cylinders, 149-150 sandpile collapse and, 68-69, 74 scaling relations for interfacial roughness, 150-151 silo walls, 247 Type II avalanches and, 118-119, 126-131 roughness exponents, 150, 163, 165, 167 spatial roughening, 128-130, 158 surface roughening, 17 temporal roughening, 119 saltation, 168-169, 171-172, 174 sand dunes, 167-168 sand ripples, 168-174 sandpiles, see also shaken sand bridge formation in, 52-54 cellular automaton models, 13-15, 70-78, 116-117 collapse, 67-69 coupled continuum equations, 148-175 dip problem, 248, 271 disorder in, 79-92, 122-124 force transmission in, 216 in rotating cylinders, 132-135 random deposition, 141-147 realistic models, 17 shape of critical, 136, 147 spatial roughening exponent, 128-130 stresses in, 226, 248-250 surface dynamics, 148-175 theoretical studies of, 15-17 tilting effects on, 71-76 saturation sandpile surfaces, 129, 154-156 saturated interfaces, 151 saturation mass in silos, 247-248, 271 sheared granular systems, 180 scale invariance absence of disorder and, 119, 121, 127 Kadanoff model, 144-145 SOC model and, 12-13, 16-17 spatial and temporal, 17 scale separation, 182-183, 185, 188, 195 scaling behaviour, see also coarse-graining dynamical scaling, 119-120 q-model, 245 scaling relations, interfacial roughness, 150-151 screening effect, silos, 247-248, 271

303

Cambridge University Press 978-0-521-18799-2 - Granular Physics Anita Mehta Index More information

304

Index

segregation of mixtures, 4 cellular automata and, 8-11, 23 processes other than shaking, 50-51 shaking-induced, 25, 46-51 self-diffusion, 42-44 self-organised criticality (SOC), 11-13, 115-116 sequential packing simulations, 19-20 shaken cylinders, 210-211 shaken sand, see also vibrated beds contact network topologies, 32 entropy of, 210 jamming limit effects, 104-114 lattice model with long-range interactions, 104-106 segregation of mixtures, 25, 46-51 simple lattice model, 94-103 simulations, 24-26, 29-40 transient response, 40-44 shape-dependent ageing, 99-100, 102-103 shear modulus, 267 shear transformation zones, 261 shear waves, 178-179 sheared flows, 176-208 boundary conditions, 196-200 correlation in, 185 q-model and, 245 response functions, 252 spin distribution function, 205 shock waves, 182 silo geometry, 233, 246-248, 270-272 simulations, see also Monte Carlo simulations amplitude cycling, 90-92 contact orientation in layers, 240-242 molecular dynamics simulations, 22-24 random packing, 19-22 shaken sand, 24-26 size segregation and, 9 vibrated powders, 7, 27-29, 40-42 single Fourier transforms coupled continuum equations, 152 mean-field equations, 166 temporal and spatial roughness, 149-150, 158-159, 161-162 tilt combined with flowing grains, 163-164 single-particle distribution function, 185-186 single-particle relaxation threshold (SPRT), 84-86, 97 size segregation, see segregation of mixtures slow degrees of freedom, 40-42, 63-64 slow dynamics as cascade process, 97 of granular clusters, 86-87 simple CA model, 94-96 three-spin model requirement, 81-82 slow relaxation modes, 63-64 smoothing asymptotic smoothing, 149, 162-163, 165, 167 fixed points, 143-154, 156 SOC (self-organised criticality), 11-13, 115-116 soft-particle simulations, 22, 24 soil mechanics, 210, 262 solidification fronts, 16 solids, granular media compared to, 1, 18

Sonine polynomials, 191, 204 spaces and partial voids, 39 spatial roughening exponent, 128-130, 158 spatial structure factor, 158-159 spin distribution function, 205 spin models on random graphs, 80 spin variable, 201-202 spontaneous crystallisation, 44-46 SPRT (single-particle relaxation threshold), 84-86, 97 stabilising angle, 37-38 stability criteria, 25 static equilibrium conditions, 234, see also force and torque balance static properties of granular materials, 233-273 statistical mechanics, 2-4, 211-215 steady-state shear, 22 stick-slip motion, 132-147 strain tensors, 259, 261, 265 stratification, 51 stress fields, 222-230 coarse-graining and, 226-230 elasticity formalism for, 264-268 Mohr-Coulomb computation, 268-270 stress indeterminacy, 235 stress response problem, 252 stress-strain relations, 263, 266-268 stress tensors, 23, 253-256, 259 frictional effects and, 203-204 isostaticity and, 217, 223 kinetic theory formulation, 193-195 Love stress tensor, 217 Mohr-Coulomb assumption, 268-269 stresses deriving from contact forces, 253-259 exponential form, 232 layered granular systems, 251 ratio of stress components, 271 scale dependency of, 183 sheared granular systems, 180 static pilings, 246-252 'stuck grains', 151, 162, 167, 174 superconductors, 2 'supercooled' behaviour, 45-46 supercritical slopes, 117 supersonic systems, 182 surface roughness, see roughness surface tension, 16 surface width, sandpile automata, 119-120, 126, 130 sustainability angle of repose and, 68 bridges, friction and, 30, 54 symmetry breaking, 6 system-spanning avalanches, 128 tapping, 40, 82-84, 211 temperatures, see effective; granular; low; tensorial and zero-temperature temporal roughening exponent, 119, 158 temporal structure factor, 159 tensorial temperature, 215

texture tensors, 241-242, 259-260

Cambridge University Press 978-0-521-18799-2 - Granular Physics Anita Mehta Index More information

> theoretical descriptions, 261-273 thermal averaging, 2 thermodynamics of the jammed state, 209-232 three-spin model, 81-82, 89 threshold driving forces, 134, 137-138 threshold instability, 115 tilting avalanche morphology and, 72-77 combined with flowing grains, 162-167 effects on sandpile stability, 70-78 ripples, 170 rotated cylinder model, 135-136, 162-167 torque, see force and torque balance tracer particles, 9-10, 47-49 transient response, vibrated beds, 40-44 transitions, glassy and fluidised regimes, 99 transmission coefficients, q-model, 243 triangular avalanches, 72-77 triaxial tests, 262, 264 TRUBAL software, 23 two-peak behaviour, 121, 139-141 two-species model, ripples and dunes, 174 two-time correlation function, 102-103, 163 Type I avalanches, 115-117 Type II avalanches, 118-131

unilaterality, contact forces, 234–236 uphill avalanches, 72–77, 121, 124 upward stabilisations, 38

velocity field and spin, 202 vibrated beds, *see also* shaken sand; tapping as non-hydrodynamic, 207

Index

attainable packing fractions, 44-6 convective instabilities in, 5-8 transient response, 40-44 viscosity, see also Bagnold number effective viscosity, 22-23 void loops, 226 voids contact networks, 218 excess void space, 106, 146 lattice model solutions and, 95 nonsequential dynamics and, 31 partial, 39 propagation, 5 volume fractions, 20, see also packing fractions coordination number and, 33 forces in granular systems and, 215-222 vibration intensity and, 29-30, 40-41 volume functions, 213, 215, 217-221, 228 vortices, 51 wave speed, 173-174 wavelength, ripple merger, 173 wedges, flow through, 4-5, 23 weighted particle heights, 9, 47-48 wet sand, 69 white noise, 59, 64, 157, 162

305

yield criteria, 233, 268–272 Young modulus, 261–263, 265, 267

zero-temperature dynamics, 106-108