

# Index

- abscissa
  - absolute conv., 314
  - conditional conv., 314
- accelerator mode, 418
- action, 255, 513, 526, 536
  - helium, 592
  - relation to period, 599
- admissible
  - periodic points, 215
  - trajectories, number of, 212
- Airy
  - equation, 519
  - function, 519
- Airy function, 520, 521, 581, 582, 584, 590
  - at a bifurcation, 521
- Airy integral, 518
- algebra, 661
  - associative, 662
  - Lie, 662
- alphabet, 153
- alternating binary tree, 170, 190
- analyticity
  - domain, 283
- anomalous diffusion, 425
- Anosov flows, 184
- antiharmonic extension, 683
- arc, 169
- area preserving
  - Hénon map, 113
  - map, 731
- Artin-Mazur zeta function, 221
- associative algebra, 662
- attractor, 35
  - basin, 35
  - Hénon, 59
  - strange, 35, 40, 263
- Aubry-Mather theory, 476
- autonomous flow, 38, 204
- average
  - chaotic, 399
  - space, 243, 257
  - time, 243, 255
- averaging, 23
- Axiom A, 362, 370
- baker's map, 125
- Balmer spectrum, 502
- basin of attraction, 35
- basis vector, 661
- BER
  - approximation, 410
- Bernoulli
  - polynomials, 350
  - shift, 350, 408
- Berry-Keating conjecture, 656
- Bessel function, 573
  - addition theorem, 575
- bi-infinite itinerary, 167
- bifurcation
  - Airy function approximation, 521
  - bizarre, 682
  - generic, 125
  - Hopf, 480
  - saddle-node, 58
- billiard, 120, 124, 125
  - map, 121
  - stability, 87, 122
  - stadium, 120, 126, 146, 383, 411, 729, 732
- billiards, 812
- binary
  - prime cycles, 156, 176
  - symbolic dynamics
    - collinear helium, 595
    - tree, alternating, 170, 190
- Birkhoff
  - coordinates, 49, 121, 126
  - ergodic theorem, 243
- Birkhoff coordinates, 812
- block
  - finite sequence, 168
- block, pruning, 169
- Bohr
  - de Broglie picture, 502
  - Sommerfeld quantization, 502, 553, 654
    - helium, 591, 600
    - Uetli Schwur, 654
- Bohr-Sommerfeld quantization, 520
- Boltzmann
  - equation, 429
- Boltzmann, L, 22
- boredom, 378, 629

- Borges, J.L., 629  
 boundary orbits, 144, 326  
 bounded operators, 744  
 Bourbaki, N., 57  
 Bowen, R., 26  
 brain, rat, 2, 27  
 branch cut, 394  
     singularity, 395  
 Bunimovich  
     stadium, *see* stadium billiard  
 Burnett coefficient, 423  
 butterfly effect, 58  
  
 $C_{3v}$  symmetry, 177, 331  
 canonical transformation, 111, 112, 668  
 Cartwright M.L., 650  
 Cartwright, M.L., 146  
 Cauchy criterion, 743  
 caustic, 530  
 ceiling function, 281, 369  
 center, 67  
 center manifold, 447  
 center of mass, 210  
 chain rule  
     matrix, 741  
 change  
     of coordinates, 94  
 chaology, *see* chaos  
 chaos, 5, 6  
     caveats, 8  
     deterministic, 25  
     diagnostics, 42  
     quantum, 26  
     skeleton of, 10, 12  
     spatiotemporal, 436  
     successes, 8  
 character  
     representation, 711  
 characteristic  
     equation, 665  
     exponent, 68  
     function, 236  
     multiplier, 85  
     polynomial, 218, 666, 713  
     value, 68  
 chicken heart palpitations, 5  
 circle map  
     critical, 483  
 class algebra, 731  
 Clebsch-Gordan  
     coefficients, 663  
 coarse-graining, 236  
 coding, *see* symbolic dynamics  
 collinear helium, 504  
     symbolic dynamics, 595  
 combinatorics  
     teaching, 162  
 complete  
     *N*-ary dynamics, 154  
 completeness  
     relation, 69, 663, 666, 714  
 complex eigenvalues, 70, 670, 863  
 complexity  
     algorithmic, 229  
 confession  
     C.N. Yang, 242  
     Kepler, 647  
     St. Augustine, 236  
 conjugacy, 95  
     invariant, 103  
     smooth, 94, 103, 106, 810  
     topological, 162  
 conjugate, hermitian, 710  
 connection formulas, 519  
 conservation  
     equation, 455  
     phase space volume, 110, 112, 113, 116, 247  
 continuity equation, 245, 247, 455, 458, 528  
 contour integral, 288  
 contracting  
     Floquet multipliers, 85  
     flow, 35, 40, 76  
     map, 82, 171  
     stability eigenvalues, 272  
 contraction  
     state space  
         Rössler, 81  
 convergence  
     abscissa of, 314  
     mediocre, 737  
     radius, 283  
     super-exponential, 354, 464  
 convexity, 268  
 coordinate  
     change, 94, 95, 808  
     longitudinal, 538  
     transformations, 106  
 Copenhagen School, xi, 654  
 correlation  
     decay  
         power law, 389  
         function, 365  
         spectrum, 365  
         time, 341  
 cost function, 465  
 covering  
     symbolic dynamics, 167  
 creeping  
     1-disk, 583  
 critical

- point, 87, 158, *see* equilibrium point
- value, 161, 420
- cumulant
  - expansion, 217, 220, 303
  - Plemelj-Smithies, 749
- curvature
  - correction, 301
  - expansion, 23, 301
- cycle, 11, *see* periodic orbit
  - expansion, 17, 301, 552
  - 3-disk, 317
  - finite subshift, 309
  - Lyapunov exponent, 309
  - stability ordered, 310
  - fundamental, 218, 301, 735
  - limit, 263
  - Lyapunov exponent, 86
  - marginal stability, 64, 89, 143
  - point, 11, 19, 168
    - admissible, 215
    - count, 222
  - prime, 168, 195, 231, 274
    - 3-disk, 196, 474
    - Hénon map, 467
  - pruning, 224
  - Rössler
    - flow, 198
  - stability, 83–90
    - Gauss map, 491
  - stable, 87
  - superstable, 87
  - unstable, 12
  - weight, 286
- cycle point, *see* periodic point
- cycles
  - Rössler flow, 209
- cyclic
  - invariance, 195
  - symmetry, 215
- cyclic group, 707, 708
- damped Newton method, 201
- Danish pastry, *see* symbol plane
- de Broglie wavelength, 522
- Debye approximation, 590
- decay
  - rate, 293
  - rate of correlations, 365
- decomposition
  - irreducible, 716
- defining
  - rep, 709
  - vector space, 709
- degree of freedom, 8, 108, 451, 514
- delta function
  - Dirac, 238, 509, 820, 848
- density, 236, 455
  - evolution, 22
  - phase space, 247
- density of states
  - average, 548
  - Green's function, 510
  - quantum, 510
- desymmetrization
  - 3-disk, 334, 832
- determinant
  - for flows, 285
  - Fredholm, 752
  - graph, 230
  - Hadamard, 283
  - spectral, 21, 216, 283
  - trace relation, 217
  - trace-class operator, 746
- deterministic dynamics, 5, 33, 244
- diagonalizing matrix, 713
- differential equations
  - ordinary
    - almost, 43, 802
- diffraction
  - Green's function, 615
  - Keller, 623
  - Sommerfeld, 623
- diffusion
  - anomalous, 425
  - constant, 258
  - equation, 456
- Diffusion Limited Aggregates, 26
- dihedral group, 707, 708
- dike map, 163, 171
- dimension
  - box counting, 381
  - fractal, 380
  - generalized, 8
  - information, 381
  - intrinsic, 8, 451
- Dirac delta derivatives, 251
- Dirac delta function, 19, 221, 238, 250, 261, 274, 456, 511, 531, 543, 820, 848
- Dirac path integral, 542
- Dirichlet series, 313
- dissipative
  - map, 82, 171
- divergence rate
  - local, 266
- divergence ultraviolet, 550
- dof, *see* degree of freedom
- doubling map, 361
- dual
  - rep, 661, 708, 709
  - space, 661, 709
  - vector space, 709

- Duffing oscillator, 37, 41, 50, 109
- dynamical
  - system, 32, 33
    - deterministic, 33
    - gradient, 43, 802
    - smooth, 33
  - systems
    - equivalent, 104
  - transitivity, 214
  - zeta function, 16, 287
    - Euler product rep., 287
- dynamical system
  - infinite, 452
  - smooth, 17, 18, 23, 228, 650, 770, 772, 774
- dynamics
  - deterministic, 5
  - hyperbolic, 156
  - irreversible, 36
  - reversible, 37
  - spatiotemporal, 25
  - stochastic, 5
  - symbolic, 10, 153, 167
  - symmetry, 130, 140
  - topological, 153, 167, 168
- edge, 169
- eigen-direction, 63
- eigenfunction
  - Perron-Frobenius operator, 348
  - energy, 507
- eigenfunctions
  - Perron-Frobenius, 348
- eigenstate, *see* eigenfunction
- eigenvalue, 292
  - Perron-Frobenius operator, 348
  - exponential spacing, 284
  - zero, 520, 535
- eigenvalues
  - complex, 70, 670, 863
- Einstein
  - diffusion formula, 456
- Einstein, A, 658
- elastic
  - scattering, 558
- elliptic
  - stability, 114
- enemy
  - thy, 389
- English
  - plain, 167
- ensemble
  - microcanonical, 268
- entire function, 348
- entropy
  - barrier, 316
- Gauss map, 497
- Kolmogorov, 125, 230, 376, 378, 383, 801, 838
  - topological, 6, 213, 226, 230
- equation
  - of variations, 62
- equilibria
  - Kuramoto-Sivashinsky, 443
- equilibrium
  - Lorenz flow, 39, 52
  - point, 38, 71, 242, 443, 467
  - Rössler flow, 40, 43, 72
  - Rössler system, 803
  - stability, 808
- equilibrium measure, *see* natural measure
- equivalence
  - of dynamical systems, 104
- equivariance, 130
- equivariant, 130, 140, *see* relative
- ergodic
  - average, 243
  - theorem
    - multiplicative, 268
  - theory, 243
- escape
  - intermittency, 398
  - rate, 12, 13, 259, 261, 305, 309, 317, 338, 351
  - rate, 3-disk, 308, 336
  - rate, vanishing, 308
  - rate, 3-disk, 317
- essential
  - spectral radius, 357
  - spectrum, 357
- essential spectral radius, 366
- Euler
  - formula, 66, 350, 835
  - limit, 74
  - product, 75, 290
  - product rep.
    - dynamical zeta function, 287
- Euler-MacLaurin
  - formula, 365
- Eulerian
  - coordinates, 34, 64
- evolution
  - group, 43, 802
  - kernel
    - probabilistic, 244
  - operator, 19, 262
    - quantum, 509
    - semigroup, 262
- expanding
  - Floquet multipliers, 85
  - stability eigenvalues, 272

- expectation value, 257, 269
- exponent
  - Floquet, 85, 86
- exponential
  - convergence, 283, 354
  - decay rate of correlations, 365
  - of a matrix, 66
- exponential proliferation, 19, 229
- extremal point, 515
- factor group, 132
- false zeros, 290
- Farey
  - map, 388, 410
  - mediant, 485
  - series, 483
  - tree, 485
- Feynman path integral, 534, 542
- Fick law, 456
- finite group, 707
- finite subshift
  - cycle expansion, 309
- first return function, 46
- first return time, 407
- fixed point, 195
  - maps, 59
  - marginally stable, 388
- Floquet
  - exponent, 77, 85, 86, 112
  - exponents, 86
  - multiplier, 68, 85, 86, 272
  - multiplier, metric invariant, 103
  - theorem, 85
- flow, 32–41
  - autonomous, 38, 204
  - contracting, 35, 40, 76
  - deterministic, 244
  - elliptic, 86
  - generator of, 245, 672
  - Hamiltonian, 108, 731
  - hyperbolic, 86, 114, 293
  - incompressible, 76, 247
  - infinite-dimensional, 435–451
  - inverse hyperbolic, 114
  - linear, 65, 80
  - linearized, 63
  - nonhyperbolic, 86
  - spectral determinant, 285
  - stability, 71
  - stationary, 38
  - stochastic, 244
  - stretch & fold, 159
- Fokker-Planck equation, 457
- form
  - normal, 101
- Fourier
  - mode
    - truncation, 438
  - fractal, 379
    - aggregates, 9
    - dimension, 380
    - geometry of nature, 9
    - probabilistic, 9
    - science, 8
  - Fredholm
    - determinant, 752
  - Fredholm theory, 355
  - Frenkel-Kontorova model, 476
  - frequency analysis, 42
  - Fresnel integral, 515, 520
  - function
    - space
      - piecewise constant, 275
  - functional, 243
    - composition, 36
    - Lyapunov, 35
  - functions
    - $L^2$  square-integrable, 367
    - analytic, 366
  - fundamental
    - cycle, 218
    - cycles, 735
    - domain, 176
      - collinear helium, 594
    - matrix, 14, 63
  - fundamental matrix, 675
  - Galerkin truncation, 440
  - Galilean invariance, 438, 451
  - Gatto Nero
    - professor, 161
  - gauge fixing, 52
  - Gauss
    - shift, *see* Gauss map
  - Gauss map, 251, 410, 484, 495
    - cycle stability, 491
    - metric entropy, 497
  - Gaussian
    - integral, 250, 422, 461, 543
    - integral,  $d$ -dimensional, 461, 531
    - noise, 780
    - probability density, 457
  - generating function, 274, 476
  - generating partition, 168
  - generator
    - of flow, 245, 672
  - Gilmore, R., 146
  - $GL(n, \mathbb{F})$ , 708
  - golden mean
    - pruning, 219
  - gradient
    - algorithm, 465

- system, 43, 802
- grammar
  - symbolic dynamics, 169
- graph, 169
  - irreducible, 169
  - Markov, 169
- Gray codes, 170
- Green's function, 511
  - analogue of, 676
  - density of states, 510
  - diffraction, 615
  - energy dependent, 509
  - regularized, 550
  - scattering, 563
  - semiclassical, 540, 542, 543
  - short distance, 539
  - trace, 509
    - long orbits, 539
- group, 707
  - $S^1$ , 707
  - cyclic, 707, 708
  - dihedral, 707, 708
  - dynamical, 37
  - evolution, 43, 802
  - finite, 129, 707
  - general linear, 708
  - Lie, 707
    - matrix, 711
    - not a, 732, 867
    - order of, 129, 707
    - representation, 711
    - semi-, 245, 672
    - symmetric, 707
- Gutzwiller
  - trace formula, 548
- Gutzwiller path integral, 542
- Gutzwiller, M., 653
- Hénon map, 203
- Hadamard determinant, 283
- Hadamard product, 551
- Hamilton
  - Jacobi equation, 523
  - equations, 523
  - principal function, 459, 526
- Hamilton-Cayley theorem, 663, 666
- Hamiltonian, 507, 524
  - dynamics, 108–116
  - flow, 731
    - spectral determinant, 287
    - stability, 110, 669
  - flows, stability, 667
  - Hénon map, 113
  - repeller, periodic orbits, 209, 816
- Hankel function, 539, 573, 590
- Harter, W. G., 731
- Heaviside function, 510
- Heisenberg, 654, 655
  - picture, 742
- Heisenberg, W, 671
- Helfand moments, 422
- helium, 591, 654
  - collinear, 44, 59, 109, 504, 609, 804
  - cycles, 209, 609
  - eigenenergies, 610
  - fundamental domain, 594
  - Poincaré section, 609
  - stabilities, 609
  - stability, 209
- Helmholtz equation, 573
- Hénon
  - attractor
    - Lyapunov exponent, 824
  - Hénon map, 55, 58, 114, 180, 465, 478
    - attractor, 59, 244
    - fixed points, 59, 180
    - Hamiltonian, 113
    - inverse, 180
    - Lyapunov exponent, 269
    - prime cycles, 467, 478
    - stability, 78, 87
    - symmetries, 731
    - transient, 467
  - Hénon, M., 58
- Hénon-Heiles
  - symbolic dynamics, 146
- hermitian
  - conjugation, 710
  - matrix, 710
- heroes
  - unsung, xi, xv
- Hessian matrix, 111
- Hilbert
  - space, 508
- Hilbert-Schmidt
  - condition, 355
  - operators, 744
- Hilbert-Weyl theorem, 130
- Holmes, P., 451
- Hopf
  - bifurcation, 480
- Hopf, Ebehardt, 480
- Hopf, Heinz, 608
- horseshoe, 179
  - complete, 182
- hydrodynamical
  - interpretation of QM, 541
- hyperbolic
  - flow, 86, 114, 293
  - non-, 22
- hyperbolicity assumption, 15, 273

- in/out nodes, 67
- inadmissible symbol sequence, 168
- incommesurate, 35
- incompressible flow, 76
- indecomposability, 214
  - metric, 154
- index
  - Maslov, *see* topological index
- index summation, repeated, 708
- indifferent
  - stability, 63
- induced map, 402
- inertial manifold, 439, 451
- infinite-dimensional flows, 435–451
- inflection point, 481
- information
  - dimension, 381
- initial
  - conditions
    - sensitivity to, 6
    - point  $x_0$ , 14, 34, 63
    - state  $x_0$ , 14, 34
- injective, 57
- integrable system, 93, 109
- integrated observable, 255, 256, 262, 266, 274, 288, 300, 736
- integration
  - Runge-Kutta, 43
- intermittency, 125, 361, 387
  - escape rate, 398
  - piecewise linear model, 390
  - resummation, 404
  - stability ordering, 312
- invariance
  - cyclic, 195
  - Galilean, 438, 451
  - of flows, 88
  - symplectic, 110, 667
- invariant, 710
  - matrix, 710
  - measure, 241
  - metric, 84, 103
  - topological, 84
  - tori, 144
  - vector, 710
- invariant density, *see* natural measure
- invariant measure
  - Gauss map, 251
- invariant subgroup, 132
- inverse
  - hyperbolic flow, 114
- inverse iteration, 200
  - Hamiltonian repeller, 209, 816
- involution, 708
- inward/outward spirals, 67
- irreducible
  - decomposition, 716
  - graph, 169
  - segment, 136
- irrep, 715
- irreversibility, 22, 36
- isotropy, 144
- isotropy subgroup, 131
- iteration, 34
  - inverse, 200
  - Hamiltonian repeller, 209, 816
  - map, 55
- itinerary, 10, 12, 50, 153, 196
  - bi-infinite, 155, 167
  - future, 161, 167
  - past, 167
- Jacobi, C.G.J., 80
- Jacobian, 76, 237
  - matrix, *see* fundamental matrix
- Jonqui  re function, 392, 411, 426, 432
- Jordan form, 666
- KAM
  - tori, 387
- Keller
  - diffraction, 623
- Keller, J.B., 652
- Keplerian orbit, 502
- kernel
  - resolving, 356
- kneading
  - determinant, 188
  - sequence, 163, 171
  - theory, 163
  - value, 163, 171
- Kolmogorov entropy, 125, 230, 376, 378, 383, 801, 838
- Koopman operator, 671, 676
- Kramers, 654
- Krein-Friedel-Lloyd formula, 565
- Kronecker delta, 661, 709
- KS, *see* Kustaanheimo-Stiefel
- Kuramoto, Y., 451
- Kuramoto-Sivashinsky
  - equilibria, 443, 446
  - system, 441, 444, 446, 451
- kurtosis, 269, 422
- Kustaanheimo-Stiefel transformation, 98, 592
- $L^2$  function space, 367
- Lagrangian, 526
  - coordinates, 34, 64
  - manifold, 527
- laminar states, 387
- Langevin equation, 457, 460
- Laplace

- transform, 20, 221, 246, 276, 277, 281, 509, 540, 673
- transform, discrete, 216, 274, 408
- Laplace, Pierre-Simon de, 4
- Laplacian
  - diagonalization, 733
  - non-local, 732
- least action principle, 196, 474
- Legendre transform, 526
- Leibniz, Gottfried Wilhelm, 4
- Letellier, C., 146
- level set, 109
- libration orbit, 596, *see* self-retracing
- Lie
  - algebra, 142, 662
  - group, 707
  - product, 662
- lifetime, 12
- lifetime matrix, 568
- limit
  - cycle, 263
- limit cycle
  - stability, 808
- linear
  - flow, 65, 80
  - space, 660
  - stability, 61, 83, 443
- linearized
  - flow, 63
- link, 169
- Liouville
  - equation, 248
  - operator, 248
  - theorem, 110, 112, 113, 116, 247
- Littlewood J.E., 650
- local
  - divergence rate, 266
  - stability, 61, 83, 443
- logistic map, *see* unimodal
- longitudinal
  - coordinate, 538
- loop
  - intersecting, 218
- Lorentz gas, 387, 410
- Lorentzian, 511, 848
- Lorenz flow, 39, 52, 72, 74, 134, 149, 159, 813
  - polar coordinates, 147, 148
  - proto-Lorenz, 149, 813
- Lorenz, E.N., 58, 146
- loxodromic, 113, 669
- Lozi map, 56, 58
- Lyapunov exponent, 6, 76, 264
  - cycle, 86
  - cycle expansion, 309
  - equilibrium, 444
- natural measure, 266
- numerical, 268
- numerically, 265
- Lyapunov functional, 35
- Lyapunov time, 6, 8, 37
- $\mathcal{M}$  state space volume, 259
- manifold
  - stable, 178
- map, 34, 54–57
  - area preserving, 731
  - contracting, 82, 171
  - dike, 163, 171
  - dissipative, 82, 171
  - expanding, 155
  - fixed point, 59
  - Hénon, 55, 465, 731
  - Hamiltonian, 113
  - prime cycles, 467
- Hamiltonian
  - Hénon, 113
- iteration, 55
- logistic, *see* unimodal
- Lozi, 56, 58
- once-folding, 180
- order preserving, 162
- orientation preserving, 731
- orientation reversing, 731
- quadratic, 56, 159
- return, 14, 46–49, 180
- sawtooth, 133, 321
- stability, 77
- stroboscopic, 808
- tent, 159
- unimodal, 158
- marginal
  - stability, 14, 63, 85, 143, 272, 361, 387
  - cycle, 64, 89, 143
  - fixed point, 388
- Markov
  - graph, 169
  - infinite, 220
  - partition, 423
  - finite, 155, 156
  - infinite, 189
  - not unique, 175
- Maslov index, *see* topological index
- material invariant, 455
- Mather, *see* Aubry-Mather theory
- matrix
  - diagonalizing, 713
  - exponential, 66, 674
  - group, 711
  - hermitian, 710
  - invariant, 710

- of variations, *see* stability matrix
- product, 662
- rep, 662
- stability, 62, 459
- Maupertuis, P.L.M. de, 196, 474
- measure, 236
  - invariant, 241
  - natural, 58, 242, 249, 257, 342, 344, 414, 657
  - smooth, 256
- mechanics
  - quantum, 507
  - statistical, 21
- mediocre
  - convergence, 737
- memory
  - finite, 166
- metric
  - indecomposability, 154, 739
  - invariant, 84, 103
    - Floquet multiplier, 103
    - transitivity, 739
- metric entropy
  - Gauss map, 497
- microcanonical ensemble, 268
- Mira, C., 58
- Misiurewicz, M., 58
- mixing, 6, 15, 244
- mode
  - normal, 732
- Moebius inversion, 223
- monodromy matrix, 77, 90, 272, 668
- Morse index, *see* topological index
- multi-scattering matrix, 575
- multifractals, 766
- multiplicative ergodic theorem, 268
- multiplier
  - characteristic, 85
  - Floquet, 68, 85
- multipoint shooting method, 201
- natural density, *see* natural measure
- natural invariant, *see* natural measure
- natural measure, 58, 207, 242, 249, 257, 266, 342, 344, 364, 414, 657
- nature
  - geometry of, 9
- Navier-Stokes equation, 435
- neighborhood, 61, 90
- Nero, G., 161
- neutral, *see* marginal
- Newton method, 200
  - convergence, 201
  - damped, 201
  - flows, 204
  - optimal surface of section, 694
- Newtonian dynamics, 108
- node, 169
- noise
  - Gaussian, 457, 460, 780
  - white, 457
- non-wandering set, 35, 181
- nonequilibrium, 414
- nonhyperbolic
  - flow, 86, 88
- norm, 743
- normal
  - divisor, 132
  - form, 101
  - mode, 732
- normal modes, 867
- obscure
  - foundations, 654
  - jargon, 153
  - topology, 441, 445
- observable, 243, 249, 255, 272, 341, 399, 407, 414, 425, 652, 671, 755, 760, 777
  - integrated, 255, 256, 262, 266, 274, 288, 300, 736
  - vector, 269
- observables, simultaneous, 715
- ODE, *see* ordinary differential equations
- ODEs, 435
- $O(n)$  group, 707
- 1-disk
  - creeping, 583
  - scattering, 574
  - semiclassical scattering, 580
- Onsager-Machlup, 460
- open systems, 12, 259
- operator
  - evolution, 262
  - Hilbert-Schmidt, 744
  - Koopman, 671, 676
  - Liouville, 248
  - norm, 743
  - Perron-Frobenius, 238, 268
  - positive, 744
  - regularization, 751
  - resolvent, 216, 246, 673
  - semigroup
    - bounded, 246, 673
  - shift, 167
  - trace-class, 744
- orbit, 34, 55, 131
  - inadmissible, 163
  - Keplerian, 502
  - periodic, 34, 168, 300, 546, 547
  - returning, 545
- order preserving map, 162

- ordering
  - spatial, 161, 182
- ordinary differential equations
  - almost, 43, 802
- partial differential equations, 435
- orientation
  - preserving map, 731
  - reversing map, 731
- orthogonality
  - relation, 69, 663, 666, 714
- Oseledec multiplicative ergodic theorem, 268
- palpitations, chicken heart, 5
- paradise
  - this side of, 336
- partial differential equations, 435
- partially hyperbolic invariant tori, 144
- partition, 153, 168
  - generating, 168
  - infinite, 171, 226, 230
  - Markov, 155
  - state space, 236
- partition function, 268
- passive scalar, 455
- past topological coordinate, 183
- path integral
  - stochastic, *see* Wiener integral
- PDE, *see* partial differential equations
- PDEs, 435
- period
  - relation to action, 599
- periodic
  - orbit, 34, 168, 300, 546, 547
    - condition, 195, 207, 464
    - extraction, 195–208, 464–474
    - Hamiltonian repeller, 209
    - inverse iteration, 200
    - multipoint shooting, 201
    - Newton method, 200–201
    - relative, 142
    - relaxation algorithm, 465
  - orbit extraction
    - Hamiltonian repeller, 816
  - point, *see* cycle point
  - unstable, 12
- Perron-Frobenius
  - matrix, 213
  - operator, 238, 268, 348
  - theorem, 364, 370, 769
- phase space, 33, *see* state space
  - 3-disk, 739
  - density, 247
- piecewise constant function, 275
- piecewise linear map, 410
  - intermittency, 390
- repeller, 260
- pinball, *see* 3-disk
  - simulator, 126, 812
- plain English, 167
- Plemelj-Smithies cumulants, 749
- Poincaré invariants, 116
- Poincaré return map, 46, 47
  - cycle, 89
  - polynomial, 55
  - stability, 78
- Poincaré section, 11, 46–54, 180
  - 3-disk, 121
  - Hénon trick, 57
  - hyperplane, 47
- Poincaré, H., 2, 7, 13
- point
  - non-wandering, 35
  - periodic, 11, 168
  - scatterer, 624
  - wandering, 35
- Poisson
  - bracket, 247, 248, 250, 667
  - resummation, 20, 405
- Pollicott, M, 407
- Pollicott, M., 268
- polylogarithm, 392
- polynomial
  - characteristic, 218
  - topological, 221
- Pomeau, Y., 58
- positive operators, 744
- potential
  - problems, 43
- power law
  - correlation decay, 389
- pressure, 268
  - thermodynamic, 268
- prime cycle, 168, 195, 231, 274
  - 3-disk, 155, 231, 474
  - binary, 156, 176
  - count, 223
  - Hénon map, 467, 478
  - ternary, 176
- primitive cycle, *see* prime cycle
- probabilistic zeta function, 407
- probability density
  - Gaussian, 457
- product
  - Lie, 662
  - matrix, 662
- profile
  - spatial, 34
- projection operator, 666, 713
- propagator, 509
  - semiclassical, 530
  - short time, 532, 539

- Van Vleck, 533
- pruning, 10, 387
  - block, 169
  - front, 184
  - golden mean, 219
  - individual cycles, 224
  - primary interval, 164
  - rules, 156
  - symbolic dynamics, 168
- pruning front
  - 3-disk, 191
- pseudocycle, 300
- quadratic map, 56
- quantization
  - Bohr-Sommerfeld, 502
  - semiclassical, 545
  - WKB, 512, 516
- quantum
  - chaos, 504, 505, 550
  - evolution, 509
  - interference, 522
  - mechanics, 507
  - potential, 541
  - propagator, 509
  - resonances, 502
  - theory, old, 654
- quantum chaology, *see* chaos, quantum
- quasiperiodicity, 35
- quotient
  - state space, 52
- quotient group, 132
- radius
  - of convergence, 283
- random matrix theory, 505
- recoding, 169, 175
- rectangle, 182
- rectification
  - flows, 95
  - maps, 101
- recurrence, 35, 153
  - time, *see* return time
- regularization, 98, 551
  - Green's function, 550
  - operator, 751
- relative
  - periodic orbit, 142
  - solutions, 277
- relaxation algorithm, 465
- renormalization, 125
- rep
  - defining, 709
  - dual, 661, 708, 709
  - matrix, 662
  - standard, 708
- repeated index summation, 708
- repeller, 12, 36, 259, 504
  - piecewise-linear, 260
  - single fixed point, 348
- representation
  - character, 711
  - equivalent, 712
  - faithful, 712
  - matrix, 711
  - regular, 712
- representation space, 708
- representative point, 33
- residue, 115
  - stability, 114
- resolvent
  - kernel, 356
  - operator, 216, 246, 673
- resonances
  - complex, 503
  - quantum, 502
  - Ruelle-Pollicott, 268, 407
- resummation
  - intermittency, 404
- return map, 14, 48, 49, 180
- return time, 407
  - distribution, 408
- returning orbit, 545
- reversible
  - dynamics, 37
- Riemann zeta function, 314, 410
- Rössler
  - attractor, 51
  - cycles, 198, 209
  - equilibria, 43, 72
  - flow, 40, 41, 43, 50, 59, 81, 152, 158, 179, 265
  - Lyapunov exponent, 269
- Rössler system, 803
  - equilibria, 803
- Roux
  - Henri, 25, 76
- Ruelle
  - Pollicott resonances, 268, 407
  - zeta function, *see* dynamical zeta function
- Ruelle, D., 26, 268, 407
- Runge-Kutta integration, 43
- running orbit
  - Lorentz gas, 418
- Rutherford, 591
- Rydberg series, 600
- $S^1$  group, 707
- saddle, 67
- saddle point, *see* stationary phase
- saddle-node bifurcation, 58

- sawtooth map, 133, 321  
 scalar multiplication, 660  
 scattering  
     3-dimensional spheres, 125  
     elastic, 558  
     Green's function, 563  
     matrix, 559  
     phase shift, 566  
     point, 624  
 Schrödinger  
     equation, 507  
     time independent, 507  
     picture, 742  
 Schrödinger, E, 671  
 section  
     Poincaré, 11, 46, 48, 49, 121  
 secular equation, 665, 666, 713  
 self-retracing cycle, 596  
 self-similar, 19  
 semiclassical  
     approximation, 523  
     Green's function, 540, 543  
     propagator, 530  
     quantization, 545  
     spectral determinant  
         collinear helium, 602  
         wave function, 529  
         semiclassical zeta function, 551  
 semiclassical resonances  
     3-disk, 793  
 semigroup, 245, 672  
     dynamical, 37  
     evolution, 262  
     operator, 246, 673  
 Sensitivity  
     initial conditions, 799  
 sensitivity to initial conditions, 6, 29, 58, 263  
 set  
     non-wandering, 181  
 shadowing, 17, 227  
     3-disk, 308  
 shift, 167  
     Bernoulli, 350, 408  
     finite type, 169  
     full, 167  
     map, 481  
     operator, 167  
     sub-, 168  
 similarity transformation, 103  
 simultaneous observables, 715  
 Sinai, Ya., 26  
 Sinai-Bowen-Ruelle measure, *see* natural measure  
 single fixed point  
     repeller, 348  
     spectral determinant, 349  
     singular value decomposition, 67  
     singular values, 67  
     singularity  
         branch cut, 395  
     Sivashinsky, G.I., 451  
     skeleton of chaos, 10, 12  
     Smale  
         wild idea, 285, 295  
     Smale, S., 9, 26, 174, 188, 230, 295, 650  
     small divisor problem, 273  
     S-matrix, 559  
     smooth, 140  
         conjugacy, 94, 103, 106, 810  
         dynamical system, 452  
         dynamics, 17, 18, 23, 33, 228, 650, 770, 772, 774  
         approximated, 734  
         Spectral determinant, 369  
         interaction, 776  
         measure, 256  
         potential, 125  
     smooth conjugacy, 103  
 Sommerfeld  
     diffraction, 623  
 space  
     analytic functions, 366  
     average, 243  
     averaging, 257  
     defining vector, 709  
     density functions, 275  
     dual, 661, 709  
     linear, 660  
     vector, 660  
 span, 661  
 spatial  
     profile, 34  
 spatiotemporal chaos, 436  
 spatiotemporal dynamics, 25  
 spectral  
     determinant, 21, 216, 283  
     1-d maps, 286  
     2-d hyperbolic Hamiltonian flow, 287  
     entire, 284, 354  
     for flows, 285  
     infinite product rep., 285  
     single fixed point, 349  
     weighted, 291  
     spectral determinant  
         1-dof, 553  
         2-dof, 554  
         radius, 349, 357  
         essential, 366  
         staircase, 510

- spectral decomposition, 70, 664, 666, 706, 715  
 spectral stability, 425  
 spectrum  
     Balmer, 502  
 specular reflection, 120  
 SRB measure, *see* natural measure  
 St. Augustine, 236  
 stability, 61–79  
     billiards, 87, 122  
     eigenvalue, *see* Floquet multiplier  
     eigenvalues, 272  
     elliptic, 273  
     exact, 91, 808  
     exponent, *see* Floquet exponent  
     flow, 71  
     Hamiltonian flow, 669  
     Hamiltonian flows, 110, 667  
     indifferent, 63  
     linear, 61, 83, 443  
     maps, 77  
     marginal, 63, 143  
     matrix, 62, 459  
     multiplier, *see* Floquet multiplier  
     neutral, *see* marginal  
     ordering  
         cycle expansions, 310  
         intermittent flows, 312  
     Poincaré map cycle, 89  
     Poincaré return map, 78  
     residue, 114  
     spectral, 425  
     structural, 181, 182, 184, 228, 425  
     window, 86
- stable  
     cycle, 87  
     manifold, 14, 178, 180  
 stadium billiard, 120, 126, 146, 383, 411, 729, 732  
 stagnation point, *see* equilibrium point  
 staircase  
     mean eigenvalue density, 603  
     spectral, 510  
 standard map, 387  
 standard representation space, 708  
 standing orbit  
     Lorentz gas, 418  
 state, 153, 169  
     set, 153  
 state space, 33  
     discretization, 268  
     partition, 236  
     volume  $\mathcal{M}$ , 259
- stationary  
     flow, 38
- phase approximation, 515, 520, 533, 546, 615, 624, 853, 854, 857  
 point, *see* equilibrium point  
 state, 241  
 stationary phase, 244, 475, 515, 518, 520, 535, 543, 572, 587, 614, 616, 787, 843  
 statistical mechanics, 21  
 steady state, *see* equilibrium point  
 Sterling formula, 520  
 stochastic  
     dynamics, 5, 244  
     path integral, *see* Wiener integral  
 Stokes theorem, 116, 527  
 stosszahlansatz, 22, 429  
 strange  
     attractor, 35, 40  
     strange attractor, 263  
     Rössler flow, 51  
     stretch & fold, 56, 159  
     strobe method, 46  
     stroboscopic map, 808  
     strongly connected graph, 169  
     structural stability, 181, 182, 184, 228, 425  
     structure constant, 662  
     structure constants, 142  
     subgroup  
         isotropy, 131  
     subshift, 168  
         finite type, 156, 169, 184, 185  
      $SU(n)$  group, 707  
     super-exponential  
         convergence, 464  
     superstable cycle, 87  
     superstable fixed point, 464  
     surface of section  
         optimal, 694  
     surjective, 57  
     survival probability, 13, *see* escape rate  
     symbol  
         sequence  
             inadmissible, 168  
             square, 182  
     symbol square, 182  
     symbolic  
         dynamics  
             at a bifurcation, 125  
             complete  $N$ -ary, 154  
             covering, 167  
     symbolic dynamics, 10, 152–170, 678–686  
         3-disk, 29, 147, 155, 813  
         binary  
             collinear helium, 595  
         coding, 169

- Markov graph, 309
- complete, 159, 181
- grammar, 169
- Hénon-Heiles, 146
- pruned, 168
- recoding, 169, 175
- unimodal, 161
- symmetric group, 707
- symmetry, 128–144
  - $C_{3v}$ , 177, 331
  - 3-disk, 137, 139, 176, 177, 331, 334, 832
  - cyclic, 215
  - discrete, 175
  - dynamical system, 130, 140
  - Hénon map, 731
- symplectic
  - form, 110
  - group  $Sp(2D)$ , 668
  - Hénon map, 113
  - integrator, 675
  - invariance, 110, 667
  - map, 112
  - transformation, 111, 188, 248
- systems
  - open, 259
- tangent
  - bundle, 37, 62
  - space, 62
- Tauberian theorem, 410
- teaching
  - combinatorics, 162
- template, 199
- tent map, 104, 106
- ternary
  - prime cycles, 176
- tessellation
  - smooth dynamics, 734
- thermodynamical
  - pressure, 268
- 3-body problem, 96, 504, 591, 647, 655
- 3-dimensional sphere
  - scattering, 125
- 3-disk
  - boundary orbits, 144, 326
  - convergence, 359, 734
  - cycle
    - analytically, 147
    - count, 145, 333, 691
    - expansion, 317
  - escape rate, 269, 308, 317, 336
  - fractal dimension, 379
  - geometry, 121
  - hyperbolicity, 273
  - phase space, 739
- pinball, 4, 122, 125
- point scatterer, 624
- prime cycles, 16, 155, 196, 231, 474
- pruning front, 191
- semiclassical resonances, 793
- shadowing, 308
- simulator, 126
- state space, 11, 50, 379
- symbolic dynamics, 10, 29, 147, 155, 813
- symmetry, 137, 139, 176, 177, 331, 334, 832
- transition matrix, 154
- time
  - arrow of, 22
  - as parametrization, 95
  - average, 243, 255, 265
  - ceiling function, *see* ceiling function
  - ordered integration, 75, 80
  - turnover, 71, 73, 664
- time delay
  - Wigner, 566
- topological
  - conjugacy, 162
  - dynamics, 153, 167–169
  - entropy, 6, 213, 226
  - future coordinate, 162
  - index, 530
  - topological index, 655
  - invariant, 84
  - parameter, 164
  - polynomial, 221
  - trace formula, 216
  - transitivity, 214
  - zeta function, 221, 222
- topological index, 548
- torus, 35
- totient function, 484
- $t_p$  cycle weight, 286
- trace
  - class operators, 577
  - formula
    - classical, 20
    - flows, 276
    - Gutzwiller, 548
    - maps, 274, 349
    - topological, 216, 221
  - local, 215
- trace-class operator, 744
  - determinant, 746
- trajectory, 34, 66
  - discrete, 55
- transfer
  - matrix, 239, 260
  - operator, 295
  - spectrum, 284

- transformation
  - canonical, 188
  - coordinate, 106
  - symplectic, 188
- transient, 35, 154, 186
- transition matrix, 154, 213, 215
  - 3-disk, 154
- transversality
  - condition, 47
- transverse
  - stability, 538
- traveling wave, *see* relative equilibrium
- Trotter product formula, 743
- truncation
  - Gälerkin, 440
- truncations
  - Fourier, 438
- turbulence, 7, 8, 450
  - problem of, 435
- turnover time, 71, 73, 664
- Ulam
  - map, skew, 239, 345, 823
  - map, tent, 251, 297
- Ulam map, 104, 106, 209
- ultraviolet divergence, 550
- unimodal
  - kneading value, 171
  - well ordered symbols, 171
- unimodal map, 158
  - symbolic dynamics, 161
- unstable
  - cycle, 12, 87
  - manifold, 14, 178, 180
  - periodic point, 12
- unsung
  - heroes, xi, xv
- UPO (Unstable Periodic Orbit), *see* periodic orbit
- van Kampen, N. G., 460
- Van Vleck
  - propagator, 533
- variational principle, 460
- vector
  - basis, 661
  - field, 37
  - invariant, 710
  - observable, 269
  - space, 660
    - defining, 709
    - dual, 709
- vector fields
  - singularities, 95
- velocity gradient matrix, 62
- vertex, 169
- visitation frequency, 242
- visitation sequence, *see* itinerary
- volume preservation, 124
- von Neumann
  - ergodicity, 676
- wandering point, 35
- wave function
  - semiclassical, 529
  - WKB, 530
- weight
  - multiplicative, 23
- well ordered symbols
  - unimodal, 171
- Wentzel-Kramers-Brillouin, 512, *see* WKB
- Wentzel-Kramers-Brillouin, 523
- Weyl rule, 549
- Weyl, H., 712
- white noise, 457
- Wiener integral, 459
- Wigner delay time, 566
- winding number, 115, 481, 482
- WKB, 523
  - connection formulas, 519
  - quantization, 512, 516
  - wave function, 530
- Yang, C.N., 242
- Young, L.-S., 58
- zero eigenvalue, 520, 535
- zeros
  - false, 290
- zeta function
  - Artin-Mazur, 221
  - dynamical, 16, 287
  - probabilistic, 407
  - Ruelle, *see* dynamical topological, 221, 222