

# Index

## A

Absorptive nonlinearity, 357  
A-causal model, 517  
Action potential, 91, 486  
Activation  
  function, 455, 480  
  level, 465  
  potential, 455  
ADALINE network, 457  
Affine linear transformation, 388  
Age class, 83, 291  
Airy equation, 42  
Algebraicity of limit cycles, 243  
All or None principle, 487  
Ampere, 31  
Ampere's law, 355  
Anemia, 330  
Angiogenesis, 268  
Angular frequency of the wave, 356  
Ants and termites, 73  
Aperiodic, 170, 317  
  behavior, 167  
Applying a damper, 431  
Arrhythmic, 432  
Artificial Intelligence Group, 459  
Artificial neural networks, 454  
Associative memory, 458, 465  
Asymptotic expansion, 103  
Asymptotically stable  
  critical point, 126  
Asynchronous updating, 469  
Attractor, 167  
Attributes, 462  
Autocatalysis, 174  
Autonomous differential equation, 37  
Autonomous system, 156  
Auxiliary system approach, 444

Average Lyapunov exponent, 324  
Axial flow compressors, 147  
Axon, 455, 486

## B

Backpropagation, 460  
  algorithm, 461  
Backward training, 342  
Ballistic propagation, 496  
Bandwidth, 356  
Barnsley's fern, 388  
Basin of attraction, 132, 167, 329, 342  
Basis, 216  
Batch data, 463  
Belousov-Zhabotinski reaction, 173, 181  
Bendixson's criteria, 100  
Bias, 455  
Bifurcating limit cycles from a center,  
  221  
Bifurcation  
  at infinity, 233  
  curve, 138  
  diagram, 137  
  point, 320  
  value, 136  
Bifurcation diagram  
  CR resonator, 359  
  Duffing equation, 201  
  Gaussian map, 327  
  logistic map, 323  
  neuromodule, 477  
  SFR resonator, 371  
Binarize, 419  
Binary half adder, 492  
Biology, 330  
Bipolar activation function, 455

- Bistability, 146, 147, 326, 371
- Bistable, 147, 176, 327, 357
  - cycle, 172
  - device, 356, 372
  - neuromodule, 476
  - optical resonator, 432
  - region, 202, 207, 359, 364, 478
  - solution, 148
- Blowflies, 318
- Bluegill sunfish, 82
- Boston housing data, 462
- Boundaries of periodic orbits, 344
- Box-counting dimension, 391, 396
- Brain functions, 454
- Bursting, 270
- Butterfly effect, 169
  
- C**
- Canonical form, 46, 47, 156
- Cantor
  - multifractal, 401
- Cantor set, 204, 382
- Capacitance, 32
- Cardioid, 345
- Cardiology, 429
- Carrying capacity, 21
- Causal model, 517
- Cavity Ring (CR) resonator, 357
- Cavity round-trip time, 358
- Cell body, 486
- Center, 49, 122, 210
  - manifold
    - theorem, 161
- Changing the system parameters, 431
- Chaologist, 430
- Chaos, 164, 165, 308, 310, 359
  - control, 475, 482
  - synchronization, 442
- Chaos control
  - OGY method, 431
  - periodic proportional pulses, 448
- Chaos game, 387
- Chaotic
  - attractor, 167, 198, 365
  - dynamics, 168
  - phenomena, 306
- Chaotic attractor
  - Hénon map, 439
  - neuromodule, 475
  - Sierpiński, 387
- Chapman cycle, 180
- Characteristic
  - equation, 288
  - exponent, 243
- Characteristic equation, 262
- Characteristic multiplier, 189
- Charge density, 355
- Chemical kinetics, 27, 66, 93, 173, 443
- Chemical law of mass action, 28
- Chemical reaction, 41
- Chemical signals, 455
- Chemical substance, 43
- Chua's circuit, 35, 93, 170, 431, 449, 521
- Circle map, 190
- Circular frequency of light, 359
- Classical symmetry argument, 212
- Classification of critical points, 51
- Climate change, 274
- Clipping problem, 399
- Clockwise bistable cycle, 559
- Clockwise hysteresis, 207, 360
- Cluster, 458
- Coarse Hölder exponent, 398
- Codimension-1 bifurcation, 152
- Codimension-2 bifurcation, 152
- Coexistence, 73
- Coexisting chaotic attractors, 329
- Col, 48
- Commutative ring, 216
- Competing species, 73, 86, 114
- Compile, 332
- Complete synchronization, 443
- Completely
  - integrable, 192
  - reduced, 218
- Complex eigenvalues, 49, 288
- Complex iterative equation, 367
- Compound interest, 286
- Computer algebra, 215
- Concentrations, 27
- Conditional Lyapunov exponents, 443
- Conductivity, 355
- Conformal mapping, 340
- Conservation of energy, 120
- Conservation of mass, 66
- Conservative, 120
- Contact rate, 180
- Content-addressable memory, 465
- Continuous Hopfield model, 465
- Control curves, 436
- Control engineering, 459
- Control parameter, 433
- Control region, 433
- Controlling chaos
  - Hénon map, 438

logistic map, 434  
 Conversational agents, 460  
 Convex closed curve, 99  
 Convoluted surfaces, 160  
 Core area of the fiber, 362  
 Corollary to Poincaré-Bendixson theorem, 96  
 Correlation dimension, 397  
 Coulomb, 31  
 Coulomb's law, 32  
 Counterclockwise hysteresis, 360  
 Coupler, 361  
 Critical point, 38, 52, 156, 160, 260  
   at infinity, 236  
 Culling, 83  
   policy, 296  
 Current, 31  
   density, 355  
 Cusp, 64  
 Cylindrical polar coordinates, 163

## D

Damping, 92  
 Damping coefficient, 241  
 Dangerous bifurcation, 146  
*Daphnia dentifera*, 82  
 Databases, 462  
 Data mining, 454  
 DDE, 257  
 Defibrillator, 432  
 Degenerate  
   critical point, 122  
   node, 50  
 Degree, 232  
 Degree lexicographical order, 217  
 Delay differential equation, 257  
 Deleted neighborhood, 96  
 Delta learning rule, 457, 460  
 Dendrites, 454, 486  
 Depolarization, 487  
 Depolarize, 493  
 Derivative of the Poincaré map test, 189  
 Desired vector, 460  
 Deterministic chaos, 165, 430  
 Deterministic system, 454  
 $D_f$ , 389  
 Dielectric, 356  
 Difference equation, 286, 482  
 Differential amplifier, 356  
 Diffraction, 42  
 Diffusion Limited Aggregates (DLA), 401

Dimension, 396  
 Direction  
   field, 46  
   vector, 46  
 Discrete Fourier transform, 421  
 Discrete Hopfield model, 469  
 Dispersive nonlinearity, 357  
 Displacement function, 211  
 Distributive laws, 216  
 Divergence test, 211  
 Do, 10  
 Domain of stability, 75, 167, 342  
 Double Hopf bifurcation, 268, 279  
 Double pendulum, 515  
 Double-coupler fiber ring resonator, 360, 376  
 Double-scroll attractor, 172  
 Double-well potential, 125  
 $D_q$ , 396  
 Driver system, 443, 445  
 Drop, 332  
 Duffing  
   system, 431, 539  
 Duffing equation, 105, 197  
 Dulac's criteria, 97  
 Dulac's theorem, 233  
 Dynamic Updating Enabled, 261

## E

$E_C$ , 161  
 Economic model, 92, 279, 290  
 Economics, 70, 331, 336, 401, 443  
 Edge detection, 425  
 Eigenvector, 51  
 Electric  
   circuit, 31, 70, 93, 170, 465  
   displacement, 355  
   displacement vector, 355  
   field, 361, 367, 432  
   field strength, 354  
   flux density, 355  
 Electric circuit, 513  
 Electromotive force (EMF), 33  
 Elliptic integral, 222  
 El Niño, 274  
 Energy level, 194  
 Enrichment of prey, 83  
 ENSO model, 274  
 Environmental effects, 83  
 Environmental model, 274  
 Epidemic, 43, 65, 83, 92, 180  
 Epoch, 457

Equilibrium point, 38  
 Ergodicity, 324, 433  
 Error backpropagation rule, 462  
 Error function, 460  
 Erythrocytes, 330  
 $E_S$ , 52, 156, 161  
 $E_U$ , 52, 156, 161  
 Euclidean dimension, 396  
 Exact differential equation, 21  
 Excitatory, 455, 486  
 Existence and uniqueness  
   limit cycle, 93  
 Existence theorem, 36  
 Extinct, 74

**F**

Fabry-Perot  
   interferometer, 357  
   resonator, 357  
 Farad, 32  
 Faraday's law, 32  
   of induction, 354  
 $f(\alpha)$  spectrum, 396  
 Fast Fourier Transform (FFT), 422  
 Feedback, 147, 357, 370  
 Feedback mechanism, 476  
 Feedforward single layer network, 457  
 Feigenbaum constant, 321  
 Fiber parameters, 373  
 Fibonacci sequence, 10, 301  
 Field, 216  
 Fine focus, 210  
 First integral, 120  
 First iterative method, 369, 373, 482  
 First return map, 186  
 First-order difference equation, 286  
 Fish population, 20, 151, 303  
 Fitzhugh-Nagumo  
   equations, 91  
   oscillator, 91  
 Fitzhugh-Nagumo system, 512  
 Fixed point, 38, 312  
   period  $m$ , 190  
   period  $N$ , 315  
   period one, 186, 363, 435  
   period two, 438  
 Fixed size box-counting algorithm, 399  
 Fixed weight box-counting algorithm,  
   399  
 Flow, 93  
 Focal values, 210  
 Fold bifurcation, 152

Forced system, 196  
 Forward rate constant, 29  
 Fossil dating, 41  
 Fourier spectrum, 421  
 Fourier transform, 266, 421  
 Fractal, 382, 389  
   attractor, 167, 389  
   dimension, 389  
   Cantor set, 390  
   Koch curve, 390  
   Koch square, 390  
   Sierpiński triangle, 390  
   geometry, 382  
   structure, 167, 170, 340  
 Fragmentation ratios, 396  
 Function approximators, 459  
 Functions, 4  
 Fundamental memory, 469  
 Fuzzy discs, 399

**G**

Gaussian input pulse, 371  
 Gaussian map, 325  
 Gaussian pulse, 567  
 Gauss-Newton method, 461  
 Gauss's law  
   electricity, 355  
   magnetism, 355  
 Generalized delta rule, 461  
 Generalized fractal dimensions, 396  
 Generalized mixed Rayleigh Liénard  
   equations, 228  
 Generalized synchronization, 445  
 Global bifurcation, 223, 233  
 Global warming, 274  
 Globally asymptotically stable, 164, 179  
 Glucose in blood, 42  
 Gröbner bases, 215  
 Gradient, 46  
 Gradient vector, 460  
 Graphene nano-ribbon, 498  
 Graphic, 95  
 Graphical method, 308, 367  
 Gray scale, 406, 419  
 Green's theorem, 97  
 Gross National Product (GNP), 331

**H**

Hénon map, 327, 393, 399, 536, 539  
 Haematopoiesis, 265  
 Hamiltonian, 119, 538  
 Hamiltonian systems

- with two degrees of freedom, 192
  - Handcrafted patterns, 474
  - Hard bifurcation, 146
  - Hartman's theorem, 58
  - Harvesting, 83, 151
    - policy, 296
  - Hausdorff dimension, 396
  - Hausdorff index, 389
  - Hausdorff-Besicovich dimension, 398
  - Heaviside function, 456
  - Hebb's learning law, 456
  - Hebb's postulate of learning, 469
  - Help pages, 3
  - Hénon-Heiles Hamiltonian, 193
  - Henry, 32
  - Heteroclinic
    - bifurcation, 203
    - orbit, 95, 123, 203, 233
    - tangle, 203
  - Heterogeneous, 396
  - Hidden layer, 458, 462
  - High pass filter, 425
  - Hilbert numbers, 232
  - History, 148
  - History function: DDEs, 258
  - Hodgkin-Huxley equations, 91
  - Holling-Tanner model, 79, 114, 136
  - Homoclinic
    - bifurcation, 170, 203, 224
    - loop, 223, 224, 228
    - orbit, 123, 203, 233
    - tangle, 203
  - Homogeneous, 395
  - Homogeneous differential equation, 22
  - Hopf
    - bifurcation, 141, 152
    - singularity, 152
  - Hopf bifurcation, 263
  - Hopfield network, 130, 465, 481, 537, 540
  - Hopfield neural network, 458
  - Horseshoe dynamics, 204
  - Host-parasite system, 82
  - Human population, 65, 301
  - Hyperbolic
    - attracting, 243
    - critical point, 58
    - fixed point, 189, 328
    - iterated function system, 388
    - repelling, 243
    - stable limit cycle, 189
    - unstable limit cycle, 189
  - Hyperpolarize, 493
  - Hyperpolarized, 487
  - Hysteresis, 147, 328, 372
- I**
- Ideal, 216
  - If, 10
  - Ikeda DDE, 270
  - Ikeda map, 332, 363, 376, 449
  - Image analysis, 401
  - Image compression, 382, 425
  - Incident, 357
  - Index, 101
  - Inductance, 32
  - Infected population, 82
  - Infectives, 65
  - Inflation unemployment model, 336
  - Information dimension, 397
  - Inhibitory, 455, 486
  - Initial value problem, 20
  - Input vector, 455
  - Insect population, 86, 302, 544
  - Instability, 371
  - Instant physician, 459
  - Integrable, 192
  - Integrate and fire neuron, 91
  - Integrating factor, 24
  - Intensity, 361
  - Interacting species, 73, 553
  - Intermittency, 172, 181, 321
    - route to chaos, 321
  - Invariant, 94, 170, 365
    - axes, 62, 76
  - Inverse discrete Fourier transform, 421
  - Inverted Koch snowflake, 536
  - Inverted Koch square, 386
  - Inverted pendulum, 279
  - Isoclines, 47
  - Isolated periodic solution, 90
  - Isothermal chemical reaction, 66
  - Iterated Function System (IFS), 388
  - Iteration, 286
- J**
- Jacobian, 142
  - Jacobian matrix, 58, 162, 175, 328, 439
  - Jaynes-Cummings model, 526
  - Jordan curve, 96, 247
  - Jth point of period  $i$ , 314
  - Julia set, 340, 343, 382, 540
- K**
- KAM

- theorem, 195
  - tori, 195
- Kernel machines, 459
- Kerr effect, 357, 362
- Kerr type, 362
- Kinetic energy, 120
- Kirchhoff's
  - current law, 32
  - laws, 465
  - voltage law, 32
- Koch
  - curve, 383
  - snowflake, 410
  - square, 384
  
- L**
- Ladybirds and aphids, 76
- Laminarize, 432
- Landolt clock, 173
- Laplace transform, 33
- Large-amplitude limit cycle, 147
  - bifurcation, 147
- Laser, 152, 331, 359, 432
- Law of mass action, 66
- Learning process, 454
- Learning rate, 460
- Least Mean Squared (LMS) algorithm, 457
- Legendre transformation, 398
- Leslie
  - matrix, 292
  - model, 291
- Lexicographical order, 217
- Liénard
  - equation, 212
- Liénard plane, 242
- Liénard system, 92, 99, 114, 223, 241
  - large parameter, 246
  - local results, 250
- Liénard's theorem, 253
- Lie detector, 459
- Limit cycle, 83, 90, 94, 175, 527, 538
  - 3-D, 164
  - hyperbolic, 222
  - neuron, 92
  - nonexistence, 535
- Lindstedt-Poincaré technique, 106
- Linear differential equation, 24
- Linearization, 58
- Linearized system, 58
- Linear phase shift, 362, 374
- Linear stability analysis, 39, 260, 366
  
- Linear transformation, 158
- Lipschitz condition, 37
- Load, 478
- Local bifurcation, 233
- Logic gates, 356
- Logistic equation, 20, 262
- Logistic growth, 79
- Logistic map, 318, 434, 539
- Logistic ODE, 510
- Log-log plot, 393
- Lorenz
  - attractor, 171
  - equations, 169, 432
- Lorenz system, 512
- Loss in the fiber, 362
- Lotka-Volterra model, 76, 136, 180
- Lowest common multiple, 219
- Low-gain saturation function, 456
- Low pass filter, 425
- Lyapunov
  - quantity, 211
  - stability, 465
- Lyapunov domain of stability, 128
- Lyapunov exponent, 168, 323, 540
- Lyapunov function, 124, 127, 163, 210, 244, 481, 534
  - Hopfield network, 465
- Lyapunov quantities, 250
- Lyapunov stability theorem, 126
- Lynx and snowshoe hares, 76
  
- M**
- Mackey-Glass model, 265
- Magnetic field vector, 354
- Magnetic flux, 354
- Magnetostrictive ribbon, 432
- Mandelbrot, 391
- Mandelbrot set, 343, 344, 382
- Manifold, 51
- Manipulate, 4, 8
- Map, 332
- Mathematica, 1
  - based exam, 533, 541
- Maximal interval of existence, 37, 43, 93
- Maxwell-Bloch equations, 356
- Maxwell-Debye equations, 356
- Maxwell's equations, 354
- McCulloch-Pitts neuron, 456
- Mean infectivity period, 180
- Mean latency period, 180
- Mechanical oscillator, 69
- Mechanical oscillator DDE, 279

- Mechanical system, 93, 148
- Melnikov
  - function, 221
  - integral, 221
- Memory devices, 356
- Memristance, 35
- Memristor, 35, 498, 500
- Meteorology, 169
- Method of multiple scales, 110
- Method of steepest descent, 460
- Method of steps, 258
- Micro-parasite—zooplankton—fish system, 82
- Minimal chaotic neuromodule, 475
- Minimal Gröbner basis, 220
- Mixed fundamental memories, 470
- Mixing, 310
- Modelica, 509
- Modulo, 218
- Monomial, 216
  - ordering, 216
- Mortgage assessment, 459
- Motif, 382
- Multidegree, 217
- Multifractal, 395, 418, 533
  - formalism, 395
  - Hénon map, 406
  - Sierpiński triangle, 406
  - spectra, 396
- Multistability, 146
- Multistable, 125, 147, 176, 207, 476
- Murder, 42
- Muscle model, 42
- Mutual exclusion, 74
- Myelin sheath, 486
  
- N**
- National income, 290
- NDSolve, 260
- Negative limit set, 94
- Negative semiorbit, 93
- Negatively invariant, 94
- NestList, 332
- Net reproduction rate, 298
- Network architecture, 455
- Neural network, 332, 443, 454
  - DDE, 276
- Neurodynamics, 474
- Neuromodule, 475
- Neuron, 91, 482, 486
  - module, 332
- Neuronal model, 455
- Neurons, 454
- Neurotransmitters, 486
- Newton fractal, 348, 532
- Newton's law of cooling, 42
- Newton's law of motion, 120
- Newton's method, 348, 461
- Noise, 434
- NOLM, 353
  - with feedback, 360
- Nonautonomous system, 92, 195
- Nonconvex closed curve, 100
- Nondegenerate
  - critical point, 122, 210
- Nondeterministic chaos, 165, 430
- Nondeterministic system, 454
- Nonexistence of limit cycles, 100
- Nonhyperbolic
  - critical point, 58, 124, 534
  - fixed point, 328
- Nonlinear
  - center, 211
  - optics, 331
- Nonlinearity, 147, 357
- Nonlinear phase shift, 362
- Nonlinear refractive index coefficient, 362
- Nonperiodic behavior, 167
- Nonsimple canonical system, 47
- Normal form, 136, 142
- Normalized eigenvector, 298
- Not robust, 78
- Notebook, 2
  
- O**
- Occasional Proportional Feedback (OPF), 431
- OGY method, 433
- Ohm, 32
- Ohm's law, 31
- Optical
  - bistability, 356
  - computer, 356
  - fiber, 359
  - fiber double ring, 360
  - memories, 356
  - resonator, 149
  - sensor, 357
- Optimal sustainable, 298
- Orbit, 46, 93
- Ordinary differential equation, 18
- Oscillation of a violin string, 90
- Output vector, 455
- Ozone production, 180

**P**

Partial differential equations, 18  
 Partition, 332  
 Partition function, 396  
 Pascal's triangle, 410  
 Passive circuit, 34  
 Peixoto's theorem in the plane, 136  
 Pendulum, 120, 131, 206  
     double, 525  
 Perceptron, 457  
 Perihelion, 525  
 Period, 221  
     bubbings, 326  
     limit cycle, 94, 175  
     of limit cycle, 82  
     undoublings, 326  
 Period-doubling, 172  
 Period-doubling bifurcations to chaos, 321  
 Period-n cycle, 164  
 Period-one behavior, 307  
 Period-three behavior, 308  
 Period-two, 166  
 Period-two behavior, 307  
 Periodic  
     orbit, 221  
     windows, 321  
 Periodic behavior, 90  
 Periodicity, 306, 310  
 Permittivity of free space, 355  
 Perturbation methods, 102  
 Phase portrait, 46  
 Phase shift, 361  
 Physiology, 443  
 Piecewise linear function, 456  
 Pinched hysteresis, 35, 500  
 Pitchfork bifurcation, 139  
 Pixels, 399  
 Planar manifold, 157  
 Plastics, 401  
 Poincaré  
     section, 186, 539  
 Poincaré map, 94, 168, 186, 222, 328, 433  
 Poincaré-Bendixson theorem, 95, 195, 241, 247  
 Poincaré compactification, 235  
 Poisson brackets, 192  
 Polar coordinates, 49, 235  
 Pole placement technique, 433  
 Pollution, 83  
 Polymer, 401  
 Population, 70  
     of rabbits, 66

Population model, 542  
 Positive limit set, 94  
 Positive semiorbit, 93  
 Positively invariant, 94  
 Potato man, 347  
 Potential difference, 31  
 Potential energy, 120, 125  
 Potential function, 124  
 Power, 361  
     of a waterwheel, 70  
     spectra, 172  
 Power law, 391  
 Power spectrum, 266  
 Power-splitting ratio, 362  
 Prandtl number, 169  
 Predation, 82  
     rate, 79  
 Predator-prey, 92  
     models, 76  
     system, 85  
 Prepend, 332  
 Probe vector, 469  
 Propagation, 362  
 Psychological profiling, 459  
 Pyragas's method, 431

**Q**

Qth moment, 396  
 Qualitative behavior, 46  
 Qualitatively equivalent, 54  
 Quasiperiodic, 478, 482  
     route to chaos, 172  
 Quasiperiodic forcing, 198  
 Quasi-periodicity, 191  
 Quasi-polynomials, 262

**R**

Rössler attractor, 164  
 Rössler system, 164  
 Radioactive decay, 538  
 Random behavior, 165  
 Rate constant, 28  
 Rate-determining steps, 29  
 Rationally independent, 191  
 Rayleigh number, 169  
 Rayleigh system, 90  
 Reaction rate equation, 28  
 Real distinct eigenvalues, 48  
 Recurrence relation, 286  
 Recurrent neural network, 458, 465  
 Red and grey squirrels, 73



- Red blood cells, 330
- Reduced Gröbner basis, 220
- Reflected, 357
- Refractive index, 357
- Refractive nonlinearity, 357
- Refuge, 83
- Regulator poles, 433
- Relative permeabilities, 355
- Relative permittivities, 355
- Repeated real eigenvalues, 50
- Repolarization, 487
- Resistance, 32
- Resonance terms, 146
- Resonant, 144
- Response system, 443, 445
- Restoring coefficient, 241
- Restoring force, 92
- Restrictions in programming, 251
- Return map, 211, 534
- Reverse rate constant, 29
- Reversed fundamental memories, 470
- Ring, 216
- Ringing, 207
- RLC circuit, 34, 92
- Roach:fish population, 296
- Robust, 81
- Rubbers, 401
  
- S**
- Saddle point, 48, 122
- Saddle-node bifurcation, 136
- Saddle-node on an invariant cycle bifurcation, 149
- Safe bifurcation, 146
- Scaling, 391, 396
- Sea lions and penguins, 73
- Seasonal effects, 84
- Seasonality, 180
- Second iterative method, 369, 373, 482
- Second order linear difference equation, 287
- Second part of Hilbert's sixteenth problem, 232
- Second-order differential equation, 33
- Secular term, 106
- Sedimentary rocks, 401
- Self-similar, 396
- Self-similar fractal, 389
- Self-similarity, 382
- Semistable
  - limit cycle, 94, 189, 246
- Semistable critical point, 39
- Sensitivity to initial conditions, 167, 306, 310, 430
- Separable differential equation, 18
- Separation of variables, 18
- Separatrix, 124
  - cycle, 224
- Series solutions, 25
- SFR, 353
  - resonator, 358, 361
- Sharks and fish, 76
- Sierpiński triangle, 386
- Sigmoid function, 456
- Signal processing, 401
- Simple canonical system, 48
- Simple nonlinear pendulum, 120
- Simply connected domain, 100
- Simulink, 518
- Singlet, 180
- Singular node, 50
- Slot, 332
- Smale horseshoe map, 203, 329
- Smale-Birkhoff theorem, 204
- Small perturbation, 39, 366
- Small-amplitude limit cycle, 210
- Soft bifurcation, 146
- Solar system, 430
- Solution curves, 19
- Solve, 220
- Soma, 455, 486
- Spatial vector, 354
- Spectrum of Lyapunov exponents, 167
- Speed of light, 356
- Spike train, 487
- Spin-glass states, 470
- Spirals, 313
- S-polynomial, 219
- Spurious steady state, 470
- SR flip-flop, 495
- Stability, 124, 160
  - diagram, 370
- Stable
  - critical point, 38, 125
  - fixed point, 319, 342
  - focus, 49
  - limit cycle, 81, 94
  - manifold, 51, 52, 59, 156, 160, 433
  - node, 48
- Staircases, 313
- Stationary point, 38
- Steady state, 34, 81
- Stiff system, 30, 180
- Stiffness, 92
- Stochastic methods, 453

Stock market analysis, 401  
 Stoichiometric equations, 29  
 Stokes's theorem, 355  
 Strange attractor, 167  
 Stretching and folding, 306  
 Strictly dominant, 294  
 Structurally
 

- stable, 81, 136
- unstable, 78, 136

 Subcritical Hopf bifurcation, 146, 170  
 Subharmonic oscillations, 198  
 Summing junction, 455  
 Supercritical Hopf bifurcation, 146  
 Supervised learning, 457  
 Susceptible population, 82  
 Susceptibles, 65  
 Sustainable, 296  
 Switches, 356  
 Synaptic cleft, 486  
 Synaptic gap, 486  
 Synaptic vesicles, 486  
 Synaptic weights, 454  
 Synchronization, 431, 442, 475  
 Synchronization of chaos, 442  
 Synchronous updating, 470  
 SystemModeler, 509

**T**

Target vector, 457, 460  
 Targeting, 434  
 $\tau(q)$ , 396  
 Taylor series expansion, 39, 58, 328, 366  
 Tent map, 306, 535  
 Three-dimensional system, 156  
 Threshold, 487  
 Threshold value, 65  
 Time series, 83, 322
 

- chaos detection, 168
- plot, 167

 Tinkerbell map, 532  
 Toda Hamiltonian, 206  
 Topological dimension, 396  
 Topologically equivalent, 54  
 Torus, 198  
 Total degree, 216  
 Totally connected, 342  
 Totally disconnected, 342  
 Training, 457  
 Trajectory, 46, 93  
 Transcritical bifurcation, 139  
 Transfer function, 455, 482  
 Transient, 34

Transmitted, 357  
 Transversal, 211  
 Transversely, 186  
 Travelling salesman problem, 465  
 Triangular pulse, 371  
 TrigReduce, 106  
 Trivial fixed point, 313  
 Turbulence, 400, 429  
 Two-neuron module, 466

**U**

Unconstrained optimization problem, 460  
 Uncoupled, 156  
 Uniform asymptotic expansion, 103  
 Uniform harvesting, 299  
 Union, 332  
 Unipolar activation function, 455  
 Uniqueness theorem, 36  
 Universality, 321  
 Unix, 1, 2  
 Unstable
 

- critical point, 38, 126
- fixed point, 319, 342
- focus, 49
- limit cycle, 94
- manifold, 51, 52, 59, 156, 160
- node, 48

 Unsupervised learning, 458

**V**

Vacuum, 355  
 Value of homes in Boston, 462  
 Van der Pol equation, 27, 105  
 Van der Pol system, 90, 222  
 Vector field, 46
 

- plot, 467

 VectorPlot, 48  
 Velocity of light, 362  
 Verhulst's equation, 20, 74  
 Virus
 

- mobile phone, 524

 Viscosity, 169  
 Viscous fingering, 382  
 Volt, 31  
 Voltage drop, 31

**W**

Water tank ODE model, 519  
 Wave equations, 354  
 Wave vector, 356

Wavelength, [356](#)  
light, [362](#)

$W_C$ , [161](#)

Windows, [1](#)

Wing rock, [147](#)

Wolfram SystemModeler Link, [518](#)

$W_S$ , [59](#), [160](#)

$W_U$ , [59](#), [160](#)

## X

XOR gate, [457](#)

X-ray spectroscopy, [401](#)

## Y

Youngest class harvesting, [297](#)

You Tube, [340](#)

## Z

$Z_q$ , [396](#)