

Index

- Adams–Bashforth method, 482, 483
Adams–Moulton method, 482, 483
ADI, *see* alternating-direction implicit (ADI) method
adjoint differential operator, 59, 179, 181
matrix, 36
adjugate matrix, 36
algebraic grid generation, 391
alternating-direction implicit (ADI) method, 318, 434–436, 439, 442, 447, 510
Amdahl’s law, 521
Arnoldi method, 317, 363–365, 369, 552, 554–556
 ARPACK, 365
 implicitly–restarted, 365
artificial diffusion, 452
associated Legendre functions, 207
attractor, 256, 296, 299
 chaotic, 311
 Lorenz, 306, 309
 strange, 256, 306
augmented function, 242, 244, 245
matrix, 27, 29, 32, 33
autonomous system, 119, 255, 263, 264, 291
balanced POD, 691, 692, 697
balanced truncation, 673, 691, 692
banded matrix, 346
basin of attraction, 256, 296, 306, 614
basis functions, 157–159, 166, 188, 197, 209, 210, 392, 396, 644, 646, 650, 651, 654
vectors, 68, 157, 250, 644, 659, 661
beam-column buckling, 174
Beam–Warming method, 516
Bessel functions, 184, 185, 201, 203
bifurcation, 256, 260, 276, 302
 diagram, 256, 286, 298, 299
 Hopf, 282, 302, 303
 subcritical, 283
 supercritical, 283, 286
pitchfork, 280, 282, 302
point, 278, 280, 298
saddle-node, 277, 278
transcritical, 279, 280
bisection method, 596, 598
BLAS, 315
block matrix, 12
block tridiagonal matrix, 419, 422, 425, 518
boundary condition convection, 410
 Dirichlet, 345, 409, 412, 416, 431, 448
 Neumann, 411, 412, 416, 418, 431, 434, 436
 nonhomogeneous, 646, 651
 Robin, 410, 411, 413, 416, 436
 singularity, 501
boundary-value problem, 100, 155, 398, 403, 407, 408
Brent’s method, 598
Burgers equation, 448, 450, 452, 502, 503, 506
butterfly effect, 308
C++, 326, 422
canonical form, 86
 Jordan, 96–98, 103, 120, 121
 quadratic, 86, 88, 141
Cayley–Hamilton theorem, 77, 122, 123
central processing unit (CPU), 328, 518, 519
CFL, *see* Courant–Friedrichs–Lewy (CFL)
 criterion
characteristic equation differential operator, 168
 matrix, 70
Chebyshev polynomials, 184, 186, 395, 650, 651, 697
Cholesky decomposition, 316, 339, 340, 419, 571
cofactor expansion, 25, 26, 39, 222
 matrix, 25, 26, 36
collocation method, 393, 395, 396, 649, 652
column space of a matrix, 24, 48–51, 54
compact finite difference, 387, 444, 446, 447, 514
computational fluid dynamics (CFD), 384, 396, 495, 522
condition number, 59, 132, 329–332, 354, 571
ill-conditioned matrix, 132, 328–330
well-conditioned matrix, 329–331

- conic curve, 84, 86
- conjugate-gradient method, 316, 354, 355, 543, 544, 547, 548, 550, 551, 555, 556, 599, 614
- consistency, 380, 381, 488
- constitutive law, 236, 596
- constrained extrema, 241
- continuous system, 156, 175, 254
- continuum mechanics, 135, 137, 236, 237
- convergence, 381
- correctness, 381
- cost function, 530
- Couette flow, 19, 465
- Coulomb potential, 206
- Courant number, 503, 516
- Courant–Friedrichs–Lewy (CFL) criterion, 503, 516
- covariance, 683–685
 - matrix, 78, 132, 681, 683–687
- Cramer’s rule, 36, 37, 80, 316
- Crank–Nicolson method, 318, 474, 475, 482, 494, 498, 499, 503, 504, 506, 511, 513, 516
- critical buckling loads, 178
- cross product, 39–41, 128, 222
- Crout’s method, 338
- curl, 221–223, 225, 229
- curve fitting, 132, 371, 529, 560, 572, 578, 581, 588
- cyclic reduction, 318, 419, 423, 425, 426, 437
- defective matrix, 78, 97
- deferred correction, 452
- degrees of freedom, 115, 175, 255, 642
- design variables, *see* optimization, design variables
- determinant, 12, 24–26, 34, 59, 328, 338
- deterministic chaos, 256, 294, 299, 301, 308
- diagonal dominance, 331, 332, 349, 354, 410, 435, 436, 449–451
- diagonal matrix, 86
- diagonalization, 68, 95–97, 100, 101, 103, 104, 111, 114, 120, 123, 125, 141, 156, 318, 663, 665, 667, 687
 - real symmetric matrix, 84, 86, 88
- difference equation, 409, 410, 423
- differential equation
 - homogeneous, 101–104, 408
 - nonhomogeneous, 108, 109
- Dirac Delta function, 393, 649
- directional derivative, 221, 546, 548
- Dirichlet boundary condition, *see* boundary condition, Dirichlet
- discrete system, 156, 174, 254
- discretization error, *see* error, discretization
- divergence, 221–223, 225, 229, 236
- divergence theorem, 225
- domain of a matrix, 51, 125, 163
- Doolittle’s method, 338
- Duffing equation, 286–288, 291, 292
 - forced, 114, 291, 293, 299, 304
- DuFort–Frankel method, 487, 488
- dyad, 42, 236
- dynamic-mode decomposition (DMD), 673, 674, 690, 692–694, 697
- eigen-decomposition, 121, 123, 687
- eigenfunctions, 156, 157, 162, 164, 166, 201, 210, 643
 - expansion, 156, 209, 383, 391, 396
 - orthogonal, 165, 182, 209, 657
- eigenproblem
 - algebraic, 64, 65, 69, 81, 163, 175, 355
 - differential, 163, 165, 175, 184, 197, 206, 207
 - generalized, 68, 78, 176, 244, 246, 365, 617
- eigensystem realization algorithm (ERA), 692, 696
- eigenvalues
 - differential operator, 164, 165
 - matrix, 59, 64, 65, 68, 69, 76, 77, 81, 125
- eigenvectors
 - generalized, 78, 97, 98, 100
 - matrix, 64, 65, 68, 69, 76, 77, 125
 - orthogonal, 81, 87, 92
 - regular, 77, 97, 98, 100
- electric circuit, 16, 17, 106, 107
- electromagnetics, 205
- elementary row operations, 26, 27, 29, 34, 51
- elliptic grid generation, 391
- elliptic partial differential equation, *see* partial differential equation, elliptic
- empirical
 - basis functions, 672
 - eigenfunctions, 672
- energy
 - ground, 209
 - ionization, 209
- equation of state, 599
 - ideal gas, 599, 600
 - van der Waals, 599, 600
- equilibrium point, 255, 258, 259, 264, 278, 289
- error
 - discretization, 380, 381, 418, 419
 - iterative convergence, 347, 380, 381, 418, 419
 - modeling, 380
 - round-off, 328–331, 347, 354, 380, 381, 386, 489, 495
 - truncation, 380, 381, 386–389, 467, 470, 499, 500, 506–508, 597, 599
- Euler buckling load, 178
- Euler’s formula, 113, 116
- explicit method, 467, 484, 485
- factored ADI method, 512, 514
- fast Fourier transform (FFT), 419, 423, 437, 575

- fast Poisson solver, 419, 426, 437
 finite difference, 20, 380, 384–386, 389
 backward difference, 385, 386
 central difference, 20, 385–387, 389
 forward difference, 20, 384–386, 388, 412
 method, 20, 318, 340, 343, 382, 384, 396, 397,
 407, 645, 651
 stencil, 387, 417, 420
 finite-element method, 318, 382, 383, 391, 396,
 397, 645, 650, 651, 697
 finite-time Lyapunov exponents, 254
 finite-volume method, 650, 651
 first-order explicit method, 318, 468, 471, 472,
 485, 489, 493, 503, 509, 516, 636
 first-order implicit method, 318, 472, 474, 496,
 498, 510, 516
 floating point operations per second (FLOPS),
 328, 520
 Floquet theory, 256
 Fortran, 325, 422
 Fourier
 power spectrum, 575
 series, 162, 184, 201, 492, 572, 574, 575, 650,
 651, 697
 transform, 423, 426, 574–577
 fractal, 298
 fractional-step method, 510, 512
 function
 even, 160
 extrema, 237
 maximum, 237
 minimum, 237
 odd, 160
 space, 157, 158, 162, 163
 fundamental mode, 117
- Galerkin
 method, 393, 395, 396, 588, 589, 646–653
 projection, 196, 210, 316, 318, 396, 484, 644,
 645, 648–650, 652, 654, 659, 661,
 663–669, 675, 689–691, 696–698
 Gauss' theorem, 226
 Gauss–Seidel method, 316, 318, 350, 352, 418,
 427–429, 439, 442, 517, 518, 555
 Gaussian elimination, 26, 27, 34, 79, 315, 316,
 324, 327, 334, 338, 343, 418
 generalized Laguerre polynomials, 208
 generalized minimum residual (GMRES) method,
 316, 354, 355, 543, 551, 554–556
 Givens rotation, 359–361
 GMRES, *see* generalized minimum residual
 (GMRES) method
 gradient, 221, 223, 225, 229, 236, 249
 Gram
 determinant, 43, 45
 matrix, 43–45, 93, 685, 691
 Gram–Schmidt orthogonalization, 46–48, 57,
 122, 132, 138, 140, 159, 324, 327, 364,
 371, 552
 Green's theorem, 226
 grid transformation, 390
 grid-independent solution, 381
- Helmholtz equation, 202
 Hermitian
 differential operator, 182
 matrix, 11, 13, 79, 91, 137, 339
 Hessenberg matrix, 12, 355, 359, 361, 364,
 552–555
 Hessian matrix, 78, 238, 239, 249, 545, 612–614
 Heun's method, 482
 Hilbert matrix, 129, 332, 333
 Hooke's law, 236, 596
 Hopf bifurcation, *see* bifurcation, Hopf
 Householder rotation, 359–361
 hydrogen atom, 206, 208, 209
 hyperbolic partial differential equation, *see* partial
 differential equation, hyperbolic
 identity matrix, 11, 34, 59
 image compression, 132, 133
 implicit method, 467, 484, 496
 index ellipsoid, 84
 initial-value problem, 100, 155, 398, 401, 402,
 466, 467
 inner product
 functions, 59, 159
 vectors, 14, 39–41, 59, 66
 interpolation, 560
 bilinear, 584
 cubic spline, 579, 581
 natural spline, 581
 not-a-knot spline, 581
 polynomial, 569, 578
 spline, 340, 531, 579
 inverse
 transformation, 54
 variational problem, 645, 648, 649, 654
 inverse of a matrix, 12, 14, 34, 59, 76, 79, 316, 339
 iterative convergence
 error, *see* error, iterative convergence
 test, 350
- Jacobi method, 316, 318, 347, 350, 351, 426, 427,
 518, 555
 Jacobian, 229, 230, 602
 Jordan canonical form, *see* canonical form, Jordan
 Julia fractal set, 614
- Kalman filter, 4, 637
 Kalman–Bucy filter, 637
 Karhunen–Loëve decomposition, 669

- Karush, Kuhn, and Tucker (KKT) equations, 540, 541
 Koopman operator, 673, 692–694
 Koopman-mode decomposition, 674, 690
 Krylov subspace, 363, 364, 552, 554–556
- Lagrange multiplier, 59, 206, 207, 241, 242, 244, 537, 540, 541, 615, 617
 Lagrangian coherent structures, 254
 Lagrangian descriptors, 254
 Lanczos method, 317, 365, 556
 LAPACK, 315
 Laplace equation, 189–191, 193, 205, 223, 404, 415, 418, 491
 Laplacian, 59, 185, 203, 206, 207, 223, 229
 law of cosines, 60
 Lax method, 516
 Lax–Wendroff method, 516, 517
 leap-frog method, 516
 least-squares method, 30, 249, 316, 393, 529, 531–535, 537, 552–555, 561, 572, 589, 590, 604, 649, 696
 penalty function, 541, 542
 performance measure, 542
 Legendre polynomials, 161, 162, 184, 186, 207, 395, 652, 697
 limit cycle, 256, 259, 283, 292, 293
 Lindstedt’s method, 310
 linear algebraic equations
 backward substitution, 27, 140, 335, 336, 339, 345
 consistent, 30, 46, 50
 forward elimination, 27, 343, 345
 forward substitution, 335, 538
 homogeneous, 22, 34, 37
 inconsistent, 30, 46, 50
 trivial solution, 34, 37, 46
 linear combination
 functions, 165
 vectors, 15, 22, 43, 44, 47, 81, 89, 103
 linear oscillator with damping, 257
 linear programming, 247, 249, 620, 628, 633
 basic variables, 629
 equality constraint, 248, 615, 620, 621, 627
 feasible space, 248, 539, 621, 625
 inequality constraint, 248, 620, 621, 624, 631
 interior-point method, 634
 nonbasic variables, 629
 positivity constraint, 620, 621, 627
 simplex method, 627, 629, 631, 634
 simplex tableau, 627, 628, 631, 633
 standard formulation, 620, 624, 627, 631
 linear-quadratic-regulator (LQR) problem, 542
 linearly dependent
 vectors, 43
- linearly independent
 functions, 158
 vectors, 43, 44, 46, 48, 57, 79
 lines, method of, 484
 Lorenz attractor, *see* attractor, Lorenz
 Lorenz model, *see* Saltzman–Lorenz model
 LQR, *see* linear-quadratic-regulator (LQR) problem
 LU decomposition, 316, 334, 336, 338–340, 418, 419, 422
 Lyapunov exponent, 308
- MacCormack method, 516, 517
 Mach number, 404
 main diagonal of a matrix, 10, 26, 34, 338
 Mathematica, 26, 83, 117, 315, 326, 333, 347, 355, 365, 422, 599, 609
 Mathieu’s equation, 276
 MATLAB, 26, 83, 117, 315, 326, 347, 355, 365, 422, 599, 609
- matrix
 addition, 13, 38
 damping, 115
 definition, 10
 left-stretch, 137
 mass, 115, 365
 multiplication with a matrix, 13, 14, 327
 multiplication with a scalar, 13
 right-stretch, 137
 stiffness, 115, 365
 Maxwell’s equations, 205
 minor matrix, 25
 modal matrix, 68, 96–98, 100, 101, 109, 122, 124, 663
 orthogonal, 86–88, 97, 103
 Mohr’s circle, 67
 moments of inertia, 67, 175
 principal, 67, 68
 Moore–Penrose inverse, *see* pseudo-inverse of a matrix
 multidisciplinary design optimization (MDO), 522
 multigrid method, 318, 437, 438, 441, 442
 coarse-grid correction (CGC), 438–443
 error, 438, 440, 443
 full multigrid (FMG), 441, 444
 full-approximation-storage (FAS), 442, 443
 interpolation operator, 439
 residual, 438–440, 443
 restriction operator, 439
 V-cycle, 440, 441, 443
 W-cycle, 443
 multistep method, 318, 467, 475, 481–483
 multiple-scales analysis, 292, 293
- natural frequencies, 68, 97, 115–119, 141, 197, 199, 204, 253, 263

- Navier–Stokes equations, 19, 300, 311, 448, 517, 643
Neumann boundary condition, *see* boundary condition, Neumann
Newton linearization, 444, 448, 452, 453, 636
Newton’s method, 413, 539, 596–602, 605, 613, 614
quasi, 613
Newton’s second law, 114, 115, 287, 379 611
Newtonian fluid, 237
nonautonomous system, 255
nonnormal
matrix, 93, 690, 692
system, 272, 273
nonlinear programming, 531, 605, 615, 620
nonuniform grid, 389, 390
norm
A-norm, 544
Frobenius, 56, 132, 683
function, 159, 184
matrix, 55, 59, 132, 329, 371
spectral, 56
vector, 39–42, 55, 59, 329
normal
matrix, 91–93, 266
modes, 116
null space of a matrix, 49–51, 54
numerical diffusion, *see* artificial diffusion
numerical stability, 332, 381, 467, 470, 489, 495, 503
gain, 471, 492–494, 497
matrix method, 489, 491
modified wavenumber analysis, 489, 494, 495
von Neumann method, 489, 492, 493, 495, 497, 512, 516
- objective function, 244, 532, 537, 539, 542, 594, 604, 605, 607, 611, 612, 620, 621
operation count, 327, 328, 346
optimal control, 634, 635
optimization, 237, 249, 529, 604
adjoint problem, 541
constraint, 530, 538, 539
convex, 530, 531, 545
cost function, *see* cost function
design variables, 604, 617, 620, 621, 627
linear programming, *see* linear programming
nonconvex, 530
nonlinear programming, *see* nonlinear programming
objective function, *see* objective function
optimality condition, 540
primal problem, 541
quadratic programming, *see* quadratic programming
- orbit, 256
periodic, 256, 299, 308–310
Orr–Sommerfeld equation, 464
orthogonal
complement, 50
functions, 159, 162
matrix, 12, 13, 26, 54, 88, 91, 93–95
projection, 170, 647, 648, 654, 659, 660, 664
vectors, 12, 38, 39, 46
outer product, 42, 59, 129, 236, 688
overdetermined system of equations, 7, 30, 529, 532, 533, 536, 539, 560, 570, 571, 589, 604
- Padé approximations, 387
parabolic partial differential equation, *see* partial differential equation, parabolic
parallel axis theorem, 86
parallel computing, 324, 518–520
partial differential equation
characteristic, 398, 400–403
domain of dependence, 401–403
domain of influence, 401–403
elliptic, 189, 398, 400, 403, 404, 407, 415, 518
hyperbolic, 196, 398, 400, 401, 404, 466, 483, 515
parabolic, 195, 398, 400, 402, 404, 466, 483
quasilinear, 398, 448
period doubling, 295, 299, 304
permittivity, 206
Petrov–Galerkin projection, 666
phase-plane portrait, 255, 256, 264, 273
Picard linearization, 448, 452
pitchfork bifurcation, *see* bifurcation, pitchfork pivoting, 338
Planck’s constant, 205
plane rotation, 359
POD, *see* proper-orthogonal decomposition (POD)
Poincaré section, 256, 286, 295, 296, 299
Poincaré–Bendixson theorem, 291
Poisson equation, 415–418, 420, 423, 426, 434, 436, 444, 445
polar decomposition, 135–137
positive semidefinite matrix, 86, 91, 123, 677
positive-definite matrix, 85, 86, 136, 137, 239, 339, 340, 419, 543, 545, 550, 556, 612
Prandtl number, 300
predictor-corrector method, 318, 481–483, 517
principal axes, 67, 68, 70, 72, 79, 86, 141
principal coordinates, 120
principal-component analysis (PCA), 132, 677, 681
principle of transmissibility, 41
probability density function, 209
products of inertia, 67
programming, 605
proper variational form, 645, 647, 648, 650

- proper-orthogonal decomposition (POD), 68, 96, 129, 132, 141, 172, 209, 531, 572, 644, 650, 661, 665, 668, 669, 671–675, 677, 678, 680–683, 686, 689–691, 694, 696
- pseudo-inverse of a matrix, 59, 131, 132, 533, 536
- pseudospectral method, 395, 652
- pseudotransient method, 491, 514
- Pythagoras theorem, 39, 60
- Python, 326, 422
- QR
 - algorithm, 96, 317, 355, 357, 359, 361, 363, 364
 - decomposition, 78, 122, 138, 140, 316, 355, 360, 361, 363, 365, 534, 536–538, 540, 555, 571
- quadratic form, 84, 86, 88, 96, 533
- quadratic formula, 595
- quadratic programming, 68, 78, 244, 531, 545, 617, 620
- quadric surface, 84, 86
- quantum mechanics, 205
- quantum number, 209
 - angular momentum, 209
 - magnetic, 209
 - orbital, 209
 - principal, 209
- radial basis function, 584
 - Gaussian, 584
 - multiquadric, 584
- range of a matrix, 44, 48, 51, 125, 163
- rank of a matrix, 28–30, 44, 46, 59, 132, 371
- Rayleigh number, 300–303, 306
- Rayleigh quotient, 558
- Rayleigh–Bénard convection, 300, 643
- Rayleigh–Ritz method, 645–648, 650, 697
- reduced row-echelon form, 27
- reduced variational form, 645, 647
- reduced-order model (ROM), 132, 204, 210, 572, 642, 644, 648, 650, 652, 654, 660, 662, 664, 665, 667, 668, 689, 690, 696, 697
- regression
 - bilinear, 582
 - cross-correlation coefficient, 563
 - least-squares, 7, 570, 586
 - linear, 560–562, 564, 566, 569, 570, 572, 573, 584–586, 643
 - normal equations, 534, 563, 571, 572, 574
 - polynomial, 568, 569, 571, 573, 578, 587, 643, 696
 - trial function, 561, 568
- regula falsi method, 596
- residual, 329, 392, 532, 539, 545, 551, 561, 571, 588–590, 646, 650, 653, 659, 662, 663
- resolvent matrix, 695
- resolvent-mode analysis, 673, 691, 694
- Reynolds number, 448, 449, 452
- Riccati equation, 637
- Richardson method, 486–488, 516
- Ritz eigenvalues, 364
- Robin boundary condition, *see* boundary condition, Robin
- ROM, *see* reduced-order model (ROM)
- root finding, 249, 594, 595
- rotation matrix, 54, 94, 137, 236
- round-off error, *see* error, round-off
- row space of a matrix, 48, 50, 51
- row-echelon form, 27, 29, 31, 35, 345
- Runge–Kutta method, 475, 482, 483, 636
- saddle point, 238, 239
- saddle-node bifurcation, *see* bifurcation, saddle-node
- Saltzman–Lorenz model, 114, 294, 299–302, 304, 308–310, 643
- scalar, 231
- Schrödinger equation, 205, 206
- Schur decomposition, 121, 122, 363
- Schwarz inequality, 56
- secant method, 596
- second-derivative test, 238, 239, 612
- self-adjoint differential operator, 156, 158, 179, 182, 183, 186, 187, 209, 647, 648, 697
- separation of variables, method of, 189, 190, 195, 197, 209, 318, 396, 657
- separatrix, 256, 290
- shape function, 397
- similar matrices, 95, 96, 356, 357
- similarity transformation, 91, 95, 96, 355, 356, 361
- simple pendulum, 259, 264, 265, 273, 276, 287, 289
- single-step method, 467, 480
- singular
 - matrix, 25, 26, 77, 329
 - values, 56, 95, 125, 126, 131, 329, 371, 585, 683
- vectors
 - left, 125, 126, 129, 585, 683, 685–687
 - right, 125, 126, 129, 585
- singular-value decomposition (SVD), 96, 123, 125, 128, 130–132, 135, 141, 316, 370, 371, 534, 536, 537, 540, 584, 586, 681, 682, 686–689, 692
- skew-Hermitian matrix, 13, 91
- skew-symmetric matrix, 11, 13, 91, 234
- slack variables, 248, 624, 625, 627, 628, 631
- snapshots, method of, 673, 674, 689, 692
- SOR, *see* successive over-relaxation (SOR)
- sparse matrix, 334, 359, 361, 363, 364, 422, 543, 551, 555
- special functions, 162

- spectral numerical method, 172, 204, 209, 318, 383, 391, 393, 396, 397, 423, 645, 650–652, 661, 668, 697
- spectral proper-orthogonal decomposition (SPOD), 674, 690
- spectral radius of a matrix, 56, 59, 77, 349–353, 363, 427–430, 490, 491
- spectral theorem, 91
- spectral-element method, 383, 397
- spectrum of a matrix, 77, 331
- spherical harmonics, 207
- splitting method, 435, 436, 451
- stability, 260
- asymptotic, 93, 260, 262, 263, 266, 278
 - continuous system, 174
 - linear, 260, 263
 - modal analysis, 263, 266
 - nonlinear system, 273
 - nonnormal system, 266, 272
 - normal system, 266
 - optimal perturbation, 273
 - stable center, 263, 265, 293
 - stable node, 264, 277, 279–283
 - stable spiral, 265, 284
 - transient growth, 93, 132, 266, 267, 272, 273, 692, 696
 - unstable node, 264, 285
 - unstable saddle, 264, 276, 278–281
 - unstable spiral, 265, 284
- state estimation, 4, 531, 586, 588–590, 696
- state-space representation, 68, 112, 258, 693
- stationary point, 237–239, 242, 302, 594
- steepest descent, method of, 539, 545, 546, 550, 599, 610, 611, 614
- Stokes' theorem, 226
- stress
- normal, 65, 67, 70, 71, 141, 233
 - principal, 67, 68, 70, 72, 73, 141, 233
 - shear, 65, 70, 233
- strong form, 396, 647
- Sturm–Liouville
- differential operator, 183, 184, 186, 187, 697
 - equation, 158, 648
- successive over-relaxation (SOR) method, 316, 318, 352, 353, 418, 429, 430, 555
- SVD, *see* singular-value decomposition (SVD)
- symmetric matrix, 11, 13, 78–81, 85, 87, 88, 91, 131, 233, 234, 339, 340, 419, 543, 545, 550, 556
- system identification, 589, 692, 696, 697
- tau method, 396
- tensor, 38, 218, 231–233, 237
- deformation gradient, 137
 - moment of inertia, 67, 78
 - product, 236
- rank, 232
- strain, 78, 233
- strain-rate, 234
- stress, 65, 67, 70, 78, 79, 141, 233
- velocity-gradient, 234
- vorticity, 234
- test function, *see* weight, function
- Thomas algorithm, 316, 340, 343, 345, 346, 410, 419, 434, 436, 447, 515, 518, 581
- Toeplitz matrix, 12, 21, 341, 490
- trace of a matrix, 59, 77
- transcritical bifurcation, *see* bifurcation, transcritical
- transformation
- coordinate, 227
 - laws, 229
 - linear, 8, 51, 64, 69, 86
 - matrix, 9, 54, 58, 64, 86, 163
 - metrics, 229
- transient growth, *see* stability, transient growth
- transonic fluid flow, 404
- transpose of a matrix, 10, 59
- trial function, 392, 393, 395, 396, 574, 587, 646, 647, 649, 650, 652, 654
- triangular matrix, 11, 26, 34, 76, 338
- left, 334
 - right, 122, 140, 334
- triangularization, 122
- tridiagonal matrix, 11, 21, 340, 341, 343, 355, 359, 361, 364, 410, 419, 425, 434, 435, 447, 496, 499, 511, 514, 581
- truncation error, *see* error, truncation
- undamped harmonic oscillator, 114
- under-relaxation, 429
- underdetermined system of equations, 30, 529, 532, 537, 541, 604, 624, 628
- undetermined coefficients, method of, 109, 110
- unitary matrix, 13, 91, 131, 137
- unsteady diffusion equation, 194, 402, 483, 489, 491, 493, 494, 496, 498, 501, 509
- upwind-downwind differencing, 448, 450, 451, 504, 506, 514, 516
- validation, 381
- van der Pol oscillator, 283
- Vandermonde matrix, 571
- variance, 683
- variation of parameters, 111
- variational grid generation, 391
- variational methods, 397, 530, 542, 635, 644, 645, 654, 678, 697
- vector
- acceleration, 115
 - addition, 38
 - definition, 10, 231

- displacement, 115
- force, 115
- resultant, 39
- scalar multiplication, 39
- space, 15, 42, 44, 46–48, 51, 79, 157, 163
- unit, 39, 46
- velocity, 115
- vorticity, 235
- verification, 381
- wave equation, 196, 205, 401, 483, 515, 517
- wave function, 205, 207, 208
- weak form, 396, 647
- weight
 - function, 159, 180, 184, 392, 396, 648, 649, 653, 654
 - vector, 659, 662
- weighted residuals, method of, 392, 393, 395–397, 588, 589, 645, 648–651, 660, 662
- Wolf sunspot number, 576, 577
- Wronskian, 158
- Young's modulus, 175, 596
- zero matrix, 11, 59