

## Index

- amplitude decay, 393
- anisotropic material, 19
- anti-resonance, 363
- area coordinates, 137
- Arnoldi method, 335
- artificial damping, 393
- aspect ratio of elements, 459
- assembly of element matrices, 60, 75, 82, 91, 124
- autocorrelation function, 418
- automatic mesh generation, 452
- axial symmetry, 33, 148
- axisymmetric elements, 153, 160
- axisymmetric shell elements, 277
  
- band limited white noise, 421
- beam elements, 72, 77, 84, 95, 108, 112
- benchmark tests, 463
- bisection method, 335
- boundary conditions
  - antisymmetric, 91, 336
  - geometric, 40
  - imposition of, 36
  - natural, 40
  - skew, 82
  - symmetric, 91, 336
- building block approach, 349
  
- central difference method, 384, 403
- central limit theorem, 415
- central moments, 414
- Cholesky decomposition, 323
- classical plate theory, 285
- complete polynomial, 47
- completeness tests, 463
- complex stiffness, 36
- component mode synthesis, 349, 446
- composites, 284
- condensation
  - massless degrees of freedom, 344
  - static, 140, 183, 321
- conditional stability, 388
- conservative force, 4
- consistent inertia matrix, 404
- constant acceleration method, 395
- constraint conditions, 12, 82
- constraint modes, 350
- coordinate systems, 78, 85
- core elements, 160
- correlation coefficient, 416
- co-spectrum matrix, 431
- covariance, 416
- cross-correlation function, 422
- cross-spectral density, 422
- Crout factorisation, 373
  
- d'Alembert's principle, 2
- damping, 2, 35, 358, 370
- damping matrix, 11
- Davidson method, 336
- deterministic forces, 413
- direct analysis, 370, 402, 426
- direction cosine array, 80
- Dirichlet conditions, 377
- discrete Kirchhoff shear elements, 240
- dissipation function, 9, 35
- Doolittle-Crout factorisation, 373
- Duhamel integral, 381
- dynamic equilibrium, 1, 62
  
- effective force, 440
- eigenproblem, 49, 316
- eigenvalues, 48, 316
- eigenvalue shift, 320
- eigenvectors, 49, 316
- element displacement functions, 55
- element distortion, 458
- element geometric properties, 451
- element material properties, 451
- element reordering, 452
- element shrinking, 452
- ensemble averages, 418
- equations of motion, 1, 8–12, 36
- ergodic process, 419
- excess of Kurtosis, 415

- expected value, 414
- explicit integration, 385
- facet shell elements, 252
- false zero energy mode tests, 462
- Fast Fourier Transform algorithm, 380
- finite element, 55
- finite element method, 53
- first moment, 414
- first-order shear deformation plate theory, 288
- flat plate bending elements, 192
- folded plates, 257
- forced vibration, 357, 413
- forward substitution, 323
- Fourier integral, 419
- Fourier series, 149, 377
- Fourier transform, 419
- free vibration, 48, 316
- front solution method, 452
- Gauss elimination, 331
- Gaussian probability distribution, 415
- Gauss–Legendre integration, 102
- generalised coordinates, 140
- generalised forces, 10
- geometric invariance, 119
- Givens' method, 335
- graphics, 452
- Guyan reduction, 344
- Hamilton's principle, 4, 7
- harmonic response, 361
- Hermitian interpolation functions, 95
- Hermitian matrix, 340, 431
- hexahedral elements, 165, 170, 183
- hidden line plot, 451
- Hierarchical finite element method, 297
- Houbolt method, 389, 408
- Householder method, 325
- implicit integration, 395
- imposed displacements, 440
- impulse response function, 381
- integration formulae, 101, 129, 156, 168
- inertia force, 1
- inertia matrix
  - Axisymmetric shell, 282
  - Axisymmetric solid, 154, 159, 160, 162
  - beam, 74, 98, 111, 302
  - facet shell, 254
  - membrane, 123, 128, 134, 138
  - middle surface shell, 276
  - plate, 196, 210, 217, 220, 227, 231, 234
  - plate stiffener, 250, 255
  - rod, 58, 93, 300, 308
  - shaft, 71
  - solid, 166, 172, 176, 181
  - three-dimensional framework, 87
  - two-dimensional framework, 79, 81
- invariance, 119
- invariance tests, 463
- isoparametric elements, 133, 143, 170, 183, 189, 239
- isotropic material, 19
- Jacobi–Davidson iterative method, 336
- Jacobian matrix, 134, 172
- Jacobi method, 335
- joining unlike elements, 459
- joint probability density, 415
- kinetic energy, 6, 21, 23, 24, 26, 28, 30, 31, 33, 34, 267, 287, 290, 294
- Kirchhoff hypothesis, 240
- Lagrange's equations, 8
- Lagrange interpolation functions, 94
- laminated plates, 285
- laminated shells, 295
- Lanczos method, 335
- least squares, 106
- Legendre polynomials, 104, 206, 297
- linear acceleration method, 394
- linear dependency, 46
- linear elements
  - axisymmetrical solid, 153
  - beam, 108
  - membrane, 120, 127, 132, 138
  - plate, 209, 234
  - rod, 56
  - shaft, 70
  - solid, 165, 170, 174, 180
- load matrix
  - axisymmetric shell, 283
  - axisymmetric solid, 159, 160, 163
  - beam, 75, 98
  - membrane, 124, 131, 136
  - middle surface shell, 277
  - plate, 199, 213, 218, 220, 228, 236
  - rod, 60, 93
  - shaft, 71
  - solid, 169, 174, 177, 182
  - three-dimensional framework, 88
  - two-dimensional framework, 80, 81
- locking of a mesh, 464
- loss factor, 36
- lower triangular matrix, 323
- LR method, 335
- lumped mass matrix, 404
- massless degrees of freedom, 344
- mass matrix, *see* inertia matrix, lumped mass matrix
- mass-proportional damping, 360
- master degrees of freedom, 343
- mean, 414
- membrane elements, 119
- mid-side nodes, 93, 140
- middle-surface shell elements, 268, 269
- modal analysis, 357, 361, 381, 430, 442

- modal constant, 362
- modal damping ratio, 359
- mode acceleration method, 435
- modelling, 458
- mode shape, 49
- multiple eigenvalue, 316
- multi-point constraints, 451
- multivariate probability density, 416
  
- narrow band process, 425
- natural coordinates, 139, 159
- natural frequencies, 48
- Newmark method, 394, 409
- Newton's second law, 1
- nodal degrees of freedom, 53
- nodeless degrees of freedom, 140, 183
- node point, 53
- node renumbering, 452
- non-axisymmetric loads, 149
- non-conservative forces, 4
- normal distribution, 415
- normalised eigenvectors, 316
- numerical integration, 101, 129, 156, 168
  
- orthogonality of eigenvectors, 322
- orthogonal matrix, 334
- orthogonal similarity transformation, 334
- orthotropic material, 19
  
- parasitic shear, 130
- patch test, 463
- peakedness, 415
- pentahedral elements, 174, 188
- period elongation, 393
- periodic excitation, 377
- periodic structures, 338
- plane strain element, 147
- plane stress element, 26
- plate elements, 192
- Poisson's ratio, 28
- positive definite matrix, 12
- positive semi-definite matrix, 12
- potential energy, 5
- power spectral density, 420
- pre- and post-processors, 450
- principle of virtual displacements, 3
- probability, 413
- probability density, 414
- probability distribution function, 414
- proportional damping, 360
  
- QL method, 335
- QR method, 335
- quadratic elements, 139, 183, 239
- quadrilateral elements, 132
- quasi-static displacements, 440
  
- random excitation, 413
- random process, 416
- random process theory, 413
  
- Rayleigh–Ritz method, 45
- Rayleigh-type damping, 359
- receptance, 362
- rectangular elements, 127
- reduced energy expressions, 152
- reduced integration, 109
- reduction technique, 344
- residual flexibility, 437
- resonance, 363
- response time history, 381
- rigid body modes, 319
- rigid links, 113
- Ritz vector analysis, 438
- rod elements, 56, 93
- rotary inertia, 25, 95
- rotationally periodic structures, 338, 444
- rotation of axes, 80
  
- Saint-Venant theory of torsion, 21
- sandwich plates and shells, 295
- semi-infinite regions, 462
- shaft elements, 70
- shape functions, 55
- shape sensitivity tests, 463
- shear deformation, 25
- shell elements, 266
- shifting of eigenvalues, 320
- shrink plot, 452
- sign count function, 327
- similarity transformation, 334
- Simpson's rule, 382
- simultaneous iteration, 335
- single element test, 463
- singular matrix, 217
- skew boundary conditions, 82
- skewness, 415
- skyline, 452
- slave degrees of freedom, 343
- soil-structure interaction, 462
- solid elements, 148
- solids of revolution, 33, 148
- space-time correlation function, 422
- spectral radius, 391
- spread, 414
- stability
  - conditional, 388
  - unconditional, 393
- standard deviation, 415
- static condensation, 140, 183, 321
- stationary process, 417
- step-by-step integration methods, 383
- stiffened plates, 248
- stiffness matrix
  - axisymmetric shell, 282
  - axisymmetric solid, 155, 159, 160, 162
  - beam, 75, 98, 110, 301
  - facet shell, 254
  - membrane, 124, 129, 135, 138
  - middle surface shell, 275
  - plate, 197, 210, 218, 220, 228, 232, 235

- stiffness matrix (*cont.*)  
 plate stiffener, 251, 256  
 rod, 59, 93, 299, 308  
 shaft, 71  
 solid, 168, 173, 176, 181  
 three-dimensional framework, 88  
 two-dimensional framework, 79, 81  
 stiffness-proportional damping, 366  
 stochastic process, 416  
 strain components, 19, 34, 266, 286  
 strain-displacement relationships, 19, 34, 267, 286, 288, 292  
 strain energy, 5, 21, 23, 24, 26, 28, 30, 31, 32, 34, 266, 273, 286, 289, 293  
 stress components, 19, 160  
 stress computation, 66, 71, 77, 106, 160, 169, 199  
 stress-strain relationships, 27, 32  
 structural damping, 35, 358  
 Sturm sequence, 326  
 sub-parametric element, 142  
 subspace iteration, 335  
 substructure analysis, 349  
 symmetry, 336, 443
- tetrahedral elements, 180, 189  
 third-order shear deformation plate theory, 290  
 three-dimensional frameworks, 84  
 time averages, 418  
 time series, 416
- torsion, 21  
 transformation of generalised eigenproblem, 322  
 transient response, 381  
 trapezium rule, 382  
 triangular decomposition, 322  
 triangular elements, 120, 138, 241  
 tri-diagonal matrix, 327  
 truncation of modes, 431  
 two-dimensional frameworks, 77
- unconditional stability, 393  
 upper triangular matrix, 373
- variance, 415  
 virtual displacement, 3  
 virtual work, 21, 25, 28, 30, 33, 34  
 viscous damping, 2, 35, 359  
 volume coordinates, 178
- warping, 21  
 wavenumber, 429  
 wavenumber/frequency spectrum, 429  
 wavenumber vector, 429  
 wave propagation, 339  
 wave receptance function, 430  
 weakly stationary process, 417  
 Wilson  $\theta$  method, 400, 409
- zero energy modes, 463