

Contents

Chapter 1. Concepts from linear algebra

1.1	Introduction	1
1.2	Linear vector spaces	1
1.3	Linear dependence	3
1.4	Bases and dimension of a vector space	5
1.5	Inner products and orthogonal vectors	6
1.6	The Gram–Schmidt orthogonalization process	8
1.7	Matrices	11
1.8	Basic matrix operations	13
1.9	Determinants	16
1.10	Inverse of a matrix	19
1.11	Partitioned matrices	21
1.12	Systems of linear equations	23
1.13	Matrix norms	27

Chapter 2. Free vibration of discrete systems

2.1	Introduction	29
2.2	The system equations of motion	29
2.3	Small motions about equilibrium points	31
2.4	Energy considerations	39
2.5	Free vibration and the eigenvalue problem	41

Chapter 3. The eigenvalue problem

3.1	General discussion	50
3.2	The general eigenvalue problem	50
3.3	The eigenvalue problem for real symmetric matrices	56
3.4	Geometric interpretation of the eigenvalue problem	62
3.5	Hermitian matrices	65
3.6	The eigenvalue problem for two nonpositive definite real symmetric matrices	68
3.7	The eigenvalue problem for real nonsymmetric matrices	70

Contents

Chapter 4. Qualitative behavior of the eigensolution	73
4.1 Introduction	73
4.2 The Rayleigh principle	74
4.3 Rayleigh's theorem for systems with constraints	84
4.4 Maximum–minimum characterization of eigenvalues	88
4.5 The inclusion principle	90
4.6 A criterion for the positive definiteness of a Hermitian matrix	94
4.7 Eigenvalues of the sum of two Hermitian matrices	96
4.8 Gerschgorin's theorems	99
4.9 First-order perturbation of the eigenvalue problem	102
Chapter 5. Computational methods for the eigensolution	110
5.1 General discussion	110
5.2 Gaussian elimination	111
5.3 Reduction to triangular form by elementary row operations	115
5.4 Computation of eigenvectors belonging to known eigenvalues	120
5.5 Matrix iteration by the power method	123
5.6 Hotelling's deflation	128
5.7 Wielandt's deflation	134
5.8 The Cholesky decomposition	135
5.9 The Jacobi method	138
5.10 Givens' method	146
5.11 Householder's method	151
5.12 Eigenvalues of a tridiagonal symmetric matrix. Sturm's theorem	157
5.13 The QR method	162
5.14 The Cholesky algorithm	172
5.15 Eigenvectors of a tridiagonal matrix	176
5.16 Inverse iteration	177
Chapter 6. Response of discrete systems	183
6.1 Introduction	183
6.2 Linear systems. The superposition principle	184
6.3 Impulse response. The convolution integral	186
6.4 Discrete-time systems	192
6.5 Response of undamped nongyroscopic systems	199
6.6 Response of undamped gyroscopic systems	204
6.7 Response of damped systems	210

6.8	Response of general dynamical systems	217
6.9	Discrete-time model for general dynamical systems	221
6.10	Stability of motion in the neighborhood of equilibrium	223
Chapter 7. Vibration of continuous systems		229
7.1	Introduction	229
7.2	Lagrange's equation for continuous systems. Boundary-value problem	230
7.3	The eigenvalue problem	239
7.4	Self-adjoint systems	242
7.5	Non-self-adjoint systems	252
7.6	Vibration of rods, shafts and strings	255
7.7	Bending vibration of bars	261
7.8	Two-dimensional problems	265
7.9	Variational characterization of the eigenvalues	274
7.10	Integral formulation of the eigenvalue problem	278
7.11	The response problem	281
Chapter 8. Discretization of continuous systems		285
8.1	Introduction	285
8.2	The Rayleigh–Ritz method	286
8.3	The assumed–modes method	298
8.4	The method of weighted residuals	301
8.5	Flutter of a cantilever aircraft wing	312
8.6	Integral formulation of the method of weighted residuals	319
8.7	Lumped–parameter method employing influence coefficients	321
8.8	System response by approximate methods	322
Chapter 9. The finite element method		328
9.1	Introduction	328
9.2	Second-order problems. Linear elements	329
9.3	Higher-degree elements. Interpolation functions	339
9.4	Fourth-order problems	346
9.5	Two-dimensional domains	349
9.6	Errors in the eigenvalues and eigenfunctions	364
9.7	Inconsistent mass matrices	365
Chapter 10. Systems with a large number of degrees of freedom		368
10.1	Introduction	368
10.2	Static condensation	369

Contents

10.3	Mass condensation	370
10.4	Simultaneous iteration	373
10.5	Subspace iteration	377
10.6	The method of sectioning	380
Chapter 11. Substructure synthesis		384
11.1	General discussion	384
11.2	Component-mode synthesis	384
11.3	Branch-mode analysis	391
11.4	Component-mode substitution	395
11.5	Substructure synthesis	401
Bibliography		410
Suggested problems		415
Author index		432
Subject index		434