

Contents

Preface xv

1 Linear Equations 2

- 1.1** Matrices and Systems of Linear Equations 3
- 1.2** Gauss-Jordan Elimination 15
- 1.3** Curve Fitting, Electrical Networks, and Traffic Flow 24
- Chapter 1 Review Exercises 32

2 Matrices 34

- 2.1** Addition, Scalar Multiplication, and Multiplication of Matrices 35
- 2.2** Properties of Matrix Operations 48
- 2.3** Symmetric Matrices and Seriation in Archaeology 59
- 2.4** The Inverse of a Matrix and Cryptography 69
- *2.5** The Leontief Input-Output Model in Economics 82
- *2.6** Markov Chains, Population Movements, and Genetics 87
- *2.7** A Communication Model and Group Relationships in Sociology 93
- Chapter 2 Review Exercises 103

3 Determinants 106

- 3.1** Introduction to Determinants 107
- 3.2** Properties of Determinants 115

*Sections marked with an asterisk are optional. The instructor can use these sections to build around the core material to give the course the desired flavor.

- 3.3** Determinants, Matrix Inverses, and Systems of Linear Equations 124
- Chapter 3 Review Exercises 132

4 General Vector Spaces 134

- 4.1** The Vector Space \mathbf{R}^n 135
- 4.2** Dot Product, Norm, Angle, and Distance 141
- 4.3** General Vector Spaces 153
- 4.4** Subspaces 158
- 4.5** Linear Combinations 163
- 4.6** Linear Dependence and Independence 170
- 4.7** Basis and Dimension 175
- 4.8** Rank 182
- 4.9** Orthonormal Vectors and Projections 192
- Chapter 4 Review Exercises 205

5 Eigenvalues and Eigenvectors 208

- 5.1** Eigenvalues and Eigenvectors 209
- 5.2** Google, Demography, and Weather Prediction 216
- 5.3** Diagonalization of Matrices 223
- 5.4** Quadratic Forms, Difference Equations, and Normal Modes 232
- Chapter 5 Review Exercises 243

6 Linear Transformations 244

- 6.1** Matrix Transformations, Rotations, and Dilations 245
- 6.2** Linear Transformations, Graphics, and Fractals 257
- 6.3** Kernel, Range, and the Rank/Nullity Theorem 270
- 6.4** One-to-One Transformations and Inverse Transformations 278
- 6.5** Transformations and Systems of Linear Equations 283
- 6.6** Coordinate Vectors 290
- 6.7** Matrix Representations of Linear Transformations 298
- Chapter 6 Review Exercises 310

7 Inner Product Spaces 312

- 7.1** Inner Product Spaces 313
- 7.2** Non-Euclidean Geometry and Special Relativity 322
- 7.3** Approximation of Functions and Coding Theory 327
- 7.4** Least Squares Curves 334
- Chapter 7 Review Exercises 345

8 Numerical Methods 346

- 8.1** Gaussian Elimination 347
- 8.2** The Method of LU Decomposition 353
- 8.3** Practical Difficulties in Solving Systems of Equations 360
- 8.4** Iterative Methods for Solving Systems of Linear Equations 369
- 8.5** Eigenvalues by Iteration and Connectivity of Networks 373
- Chapter 8 Review Exercises 383

9 Linear Programming 384

- 9.1** A Geometrical Introduction to Linear Programming 385
- 9.2** The Simplex Method 393
- 9.3** Geometrical Explanation of the Simplex Method 399
- Chapter 9 Review Exercises 405

Appendices 406

- A** Cross Product 407
- B** Equations of Planes and Lines in Three-Space 417
- C** Graphing Calculator Manual 425
 - C1** Reduced Echelon Form of a Matrix 425
 - C2** Matrix Operations 426
 - C3** Powers of a Matrix 426
 - C4** Transpose of a Matrix 427
 - C5** Inverse of a Matrix 427

- C6** Determinant of a Matrix 427
- C7** Summary of Formats for Row Operations 428
- D** MATLAB Manual 429
 - D1** Entering and Displaying a Matrix (Section 1.1) 430
 - D2** Solving Systems of Linear Equations (Sections 1.1–1.3) 431
 - D3** Matrix Operations (Sections 2.1, 2.2) 435
 - D4** Computational Considerations (Section 2.2) 438
 - D5** Inverse of a Matrix (Section 2.4) 439
 - D6** Solving Systems of Equations Using Matrix Inverse (Section 2.4) 440
 - D7** Cryptography (Section 2.4) 443
 - D8** Leontief I/O Model (Section 2.5) 444
 - D9** Markov Chains (Sections 2.6, 5.2) 445
 - D10** Digraphs (Section 2.7) 448
 - D11** Determinants (Sections 3.1–3.3) 450
 - D12** Cramer's Rule (Section 3.3) 451
 - D13** Dot Product, Norm, Angle, Distance (Section 4.2) 452
 - D14** Linear Combinations, Dependence, Basis, Rank (Sections 4.5–4.8) 454
 - D15** Projection, Gram-Schmidt Orthogonalization (Section 4.9) 456
 - D16** Eigenvalues and Eigenvectors (Sections 5.1, 5.2) 458
 - D17** Transformations Defined by Matrices (Sections 6.1, 6.2) 460
 - D18** Fractals (Section 6.2) 462
 - D19** Kernel and Range (Section 6.3) 464
 - D20** Inner Product, Non-Euclidean Geometry (Sections 7.1, 7.2) 465
 - D21** Space–Time Travel (Section 7.2) 468
 - D22** Pseudoinverse and Least Squares Curves (Section 7.4) 469
 - D23** *LU* Decomposition (Section 8.2) 473
 - D24** Condition Number of a Matrix (Section 8.3) 475

- D25** Jacobi and Gauss-Seidel Iterative Methods
(Section 8.4) 476
- D26** The Simplex Method in Linear Programming
(Section 9.2) 478
- D27** Cross Product (Appendix A) 480
- D28** MATLAB Commands, Functions, and M-Files 481
- D29** The Linear Algebra with Applications Toolbox M-Files 481

Answers to Selected Exercises 483

Index 527