

Linear Algebra

and Its Applications



4th Edition

Contents

Preface	ix
A Note to Students	xv

Chapter 1 Linear Equations in Linear Algebra 1

INTRODUCTORY EXAMPLE: Linear Models in Economics and Engineering	1
1.1 Systems of Linear Equations	2
1.2 Row Reduction and Echelon Forms	12
1.3 Vector Equations	24
1.4 The Matrix Equation $Ax = b$	34
1.5 Solution Sets of Linear Systems	43
1.6 Applications of Linear Systems	49
1.7 Linear Independence	55
1.8 Introduction to Linear Transformations	62
1.9 The Matrix of a Linear Transformation	70
1.10 Linear Models in Business, Science, and Engineering	80
Supplementary Exercises	88

Chapter 2 Matrix Algebra 91

INTRODUCTORY EXAMPLE: Computer Models in Aircraft Design	91
2.1 Matrix Operations	92
2.2 The Inverse of a Matrix	102
2.3 Characterizations of Invertible Matrices	111
2.4 Partitioned Matrices	117
2.5 Matrix Factorizations	123
2.6 The Leontief Input-Output Model	132
2.7 Applications to Computer Graphics	138
2.8 Subspaces of \mathbb{R}^n	146
2.9 Dimension and Rank	153
Supplementary Exercises	160

Chapter 3 Determinants 163

INTRODUCTORY EXAMPLE: Random Paths and Distortion	163
3.1 Introduction to Determinants	164
3.2 Properties of Determinants	169

3.3	Cramer's Rule, Volume, and Linear Transformations	177
	Supplementary Exercises	181

Chapter 4 Vector Spaces 189

	INTRODUCTORY EXAMPLE: Space Flight and Control Systems	189
4.1	Vector Spaces and Subspaces	190
4.2	Null Spaces, Column Spaces, and Linear Transformations	198
4.3	Linearly Independent Sets, Bases	208
4.4	Coordinate Systems	214
4.5	The Dimension of a Vector Space	225
4.6	Rank	230
4.7	Change of Basis	239
4.8	Applications to Difference Equations	244
4.9	Applications to Markov Chains	253
	Supplementary Exercises	261

Chapter 5 Eigenvalues and Eigenvectors 265

	INTRODUCTORY EXAMPLE: Dynamical Systems and Spotted Owls	265
5.1	Eigenvectors and Eigenvalues	266
5.2	The Characteristic Equation	273
5.3	Diagonalization	281
5.4	Eigenvectors and Linear Transformations	288
5.5	Complex Eigenvalues	295
5.6	Discrete Dynamical Systems	301
5.7	Applications to Differential Equations	311
5.8	Iterative Estimates for Eigenvalues	319
	Supplementary Exercises	326

Chapter 6 Orthogonality and Least Squares 329

	INTRODUCTORY EXAMPLE: The North American Datum and GPS Navigation	329
6.1	Inner Product, Length, and Orthogonality	330
6.2	Orthogonal Sets	338
6.3	Orthogonal Projections	347
6.4	The Gram-Schmidt Process	354
6.5	Least Squares Problems	360
6.6	Applications to Linear Models	365
6.7	Inner Product Spaces	376
6.8	Applications of Inner Product Spaces	383
	Supplementary Exercises	390

Chapter 7 Symmetric Matrices and Quadratic Forms 393

INTRODUCTORY EXAMPLE: Multichannel Image Processing	393
7.1 Diagonalization of Symmetric Matrices	395
7.2 Quadratic Forms	401
7.3 Constrained Optimization	408
7.4 The Singular Value Decomposition	414
7.5 Applications to Image Processing and Statistics	424
Supplementary Exercises	432

Chapter 8 The Geometry of Vector Spaces 435

INTRODUCTORY EXAMPLE: The Platonic Solids	435
8.1 Affine Combinations	436
8.2 Affine Independence	444
8.3 Convex Combinations	454
8.4 Hyperplanes	461
8.5 Polytopes	469
8.6 Curves and Surfaces	481

Chapter 9 Optimization (Online)

INTRODUCTORY EXAMPLE: The Berlin Airlift	
9.1 Matrix Games	
9.2 Linear Programming—Geometric Method	
9.3 Linear Programming—Simplex Method	
9.4 Duality	

Chapter 10 Finite-State Markov Chains (Online)

INTRODUCTORY EXAMPLE: Google and Markov Chains	
10.1 Introduction and Examples	
10.2 The Steady-State Vector and Google's PageRank	
10.3 Communication Classes	
10.4 Classification of States and Periodicity	
10.5 The Fundamental Matrix	
10.6 Markov Chains and Baseball Statistics	