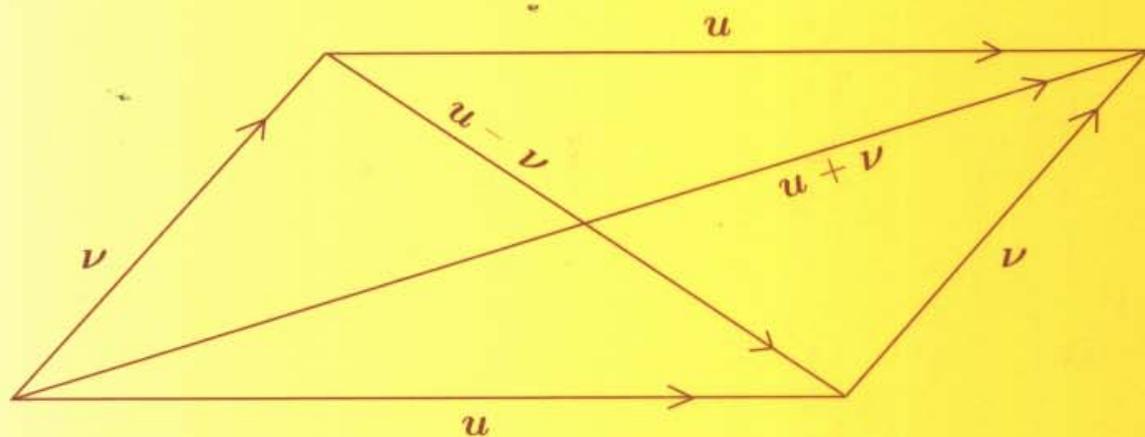


Sheldon Axler

LINEAR ALGEBRA DONE RIGHT

Second Edition



Springer

Contents

Preface to the Instructor	ix
Preface to the Student	xiii
Acknowledgments	xv
CHAPTER 1	
Vector Spaces	1
Complex Numbers	2
Definition of Vector Space	4
Properties of Vector Spaces	11
Subspaces	13
Sums and Direct Sums	14
Exercises	19
CHAPTER 2	
Finite-Dimensional Vector Spaces	21
Span and Linear Independence	22
Bases	27
Dimension	31
Exercises	35
CHAPTER 3	
Linear Maps	37
Definitions and Examples	38
Null Spaces and Ranges	41
The Matrix of a Linear Map	48
Invertibility	53
Exercises	59

CHAPTER 4	
Polynomials	63
Degree	64
Complex Coefficients	67
Real Coefficients	69
Exercises	73
CHAPTER 5	
Eigenvalues and Eigenvectors	75
Invariant Subspaces	76
Polynomials Applied to Operators	80
Upper-Triangular Matrices	81
Diagonal Matrices	87
Invariant Subspaces on Real Vector Spaces	91
Exercises	94
CHAPTER 6	
Inner-Product Spaces	97
Inner Products	98
Norms	102
Orthonormal Bases	106
Orthogonal Projections and Minimization Problems	111
Linear Functionals and Adjoints	117
Exercises	122
CHAPTER 7	
Operators on Inner-Product Spaces	127
Self-Adjoint and Normal Operators	128
The Spectral Theorem	132
Normal Operators on Real Inner-Product Spaces	138
Positive Operators	144
Isometries	147
Polar and Singular-Value Decompositions	152
Exercises	158
CHAPTER 8	
Operators on Complex Vector Spaces	163
Generalized Eigenvectors	164
The Characteristic Polynomial	168
Decomposition of an Operator	173

Contents

Square Roots	177
The Minimal Polynomial	179
Jordan Form	183
Exercises	188
 CHAPTER 9	
Operators on Real Vector Spaces	193
Eigenvalues of Square Matrices	194
Block Upper-Triangular Matrices	195
The Characteristic Polynomial	198
Exercises	210
 CHAPTER 10	
Trace and Determinant	213
Change of Basis	214
Trace	216
Determinant of an Operator	222
Determinant of a Matrix	225
Volume	236
Exercises	244
 Symbol Index	 247
 Index	 249

UNDERGRADUATE TEXTS IN MATHEMATICS

This text for a second course in linear algebra is aimed at math majors and graduate students. The novel approach taken here banishes determinants to the end of the book and focuses on the central goal of linear algebra: understanding the structure of linear operators on vector spaces.

The author has taken unusual care to motivate concepts and to simplify proofs. For example, the book presents—without having defined determinants—a clean proof that every linear operator on a finite-dimensional complex vector space (or an odd-dimensional real vector space) has an eigenvalue. A variety of interesting exercises in each chapter helps students understand and manipulate the objects of linear algebra.

No prerequisites are assumed other than the usual demand for suitable mathematical maturity. Thus, the text starts by discussing vector spaces, linear independence, span, basis, and dimension. Students are introduced to inner-product spaces in the first half of the book and shortly thereafter to the finite-dimensional spectral theorem.

This second edition includes a new section on orthogonal projections and minimization problems. The sections on self-adjoint operators, normal operators, and the spectral theorem have been rewritten. New examples and new exercises have been added, several proofs have been simplified, and hundreds of minor improvements have been made throughout the text.

ISBN 0-387-98258-2
www.springer-ny.com

