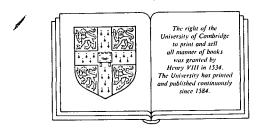
Combinatorial Matrix Theory

RICHARD A. BRUALDI University of Wisconsin HERBERT J. RYSER

Ò



CAMBRIDGE UNIVERSITY PRESS

Cambridge New York Port Chester Melbourne Sydney

CONTENTS

Preface		
Incidence Matrices		1
Fundamental Concepts		1
A Minimax Theorem		6
Set Intersections		11
Applications		17
Matrices and Graphs		23
Basic Concepts		23
The Adjacency Matrix of a Graph		24
The Incidence Matrix of a Graph		29
Line Graphs	•	35
The Laplacian Matrix of a Graph		38
Matchings		44
Matrices and Digraphs		53
Basic Concepts		53
Irreducible Matrices		55
Nearly Reducible Matrices		61
Index of Imprimitivity and Matrix Powers		68
Exponents of Primitive Matrices		78
Eigenvalues of Digraphs		88
Computational Considerations		96
Matrices and Bipartite Graphs		107
Basic Facts		107
Fully Indecomposable Matrices	•	110
Nearly Decomposable Matrices		118
Decomposition Theorems		125
Diagonal Structure of a Matrix	:	136
Some Special Graphs		145
Regular Graphs	;	145
	Incidence Matrices Fundamental Concepts A Minimax Theorem Set Intersections Applications Matrices and Graphs Basic Concepts The Adjacency Matrix of a Graph The Incidence Matrix of a Graph Line Graphs The Laplacian Matrix of a Graph Matchings Matrices and Digraphs Basic Concepts Irreducible Matrices Nearly Reducible Matrices Index of Imprimitivity and Matrix Powers Exponents of Primitive Matrices Eigenvalues of Digraphs Computational Considerations Matrices and Bipartite Graphs Basic Facts Fully Indecomposable Matrices Decomposition Theorems Diagonal Structure of a Matrix Some Special Graphs	Incidence Matrices Fundamental Concepts A Minimax Theorem Set Intersections Applications Matrices and Graphs Basic Concepts The Adjacency Matrix of a Graph The Incidence Matrix of a Graph Line Graphs The Laplacian Matrix of a Graph Matchings Matrices and Digraphs Basic Concepts Irreducible Matrices Nearly Reducible Matrices Index of Imprimitivity and Matrix Powers Exponents of Primitive Matrices Eigenvalues of Digraphs Computational Considerations Matrices and Bipartite Graphs Basic Facts Fully Indecomposable Matrices Decomposition Theorems Diagonal Structure of a Matrix Some Special Graphs

Contents

5.2	Strongly Regular Graphs	148
5.3	Polynomial Digraphs	157
6	Existence Theorems	164
6.1	Network Flows	164
6.2	Existence Theorems for Matrices	172
6.3	Existence Theorems for Symmetric Matrices	179
6.4	More Decomposition Theorems	184
6.5	A Combinatorial Duality Theorem	188
7	The Permanent	198
7.1	Basic Properties	198
7.2	Permutations with Restricted Positions	201
7.3	Matrix Factorization of the Permanent and the Determinant	209
7.4	Inequalities	214
7.5	Evaluation of Permanents	235
8	Latin Squares	250
8.1	Latin Rectangles	250
8.2	Partial Transversals	254
8.3	1 Partial Latin Squares	259
8.4	Orthogonal Latin Squares	269
8.5	Enumeration and Self-Orthogonality	284
9	Combinatorial Matrix Algebra	291
9.1	The Determinant	291
9.2	The Formal Incidence Matrix	293
9.3	The Formal Intersection Matrix	304
9.4	MacMahon's Master Theorem	310
9.5	The Formal Adjacency Matrix	317
9.6	The Formal Laplacian Matrix	324
9.7	Polynomial Identities	327
9.8	Generic Nilpotent Matrices	335
Mas	ster Reference List	345
Ind	•	363