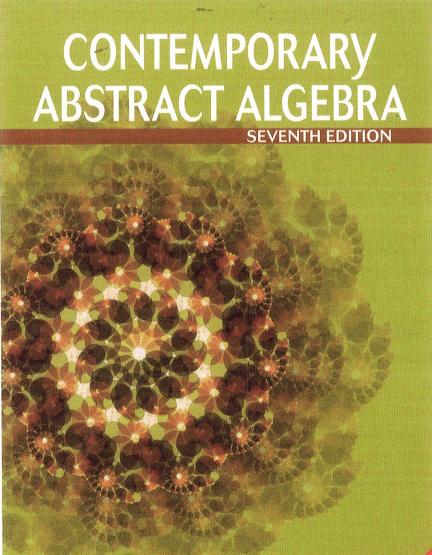
INTERNATIONAL EDITION



Not for sale in the JOSEPH A. GALLIAN

Contents

Preface xi

PART I Integers and Equivalence Relations 1

0 Preliminaries 3

Properties of Integers 3 | Modular Arithmetic 7 |
Mathematical Induction 12 | Equivalence Relations 15 |
Functions (Mappings) 18

Exercises 21

Computer Exercises 25

PART 2 Groups 27

1 Introduction to Groups 29

Symmetries of a Square 29 | The Dihedral Groups 32 Exercises 35 Biography of Niels Abel 39

2 Groups 40

Definition and Examples of Groups 40 | Elementary Properties of Groups 48 | Historical Note 51 Exercises 52 Computer Exercises 55

3 Finite Groups; Subgroups 57

Terminology and Notation 57 | Subgroup Tests 58 | Examples of Subgroups 61 | Exercises 64 | Computer Exercises 70

4 Cyclic Groups 72

Properties of Cyclic Groups 72 | Classification of Subgroups of Cyclic Groups 77

Exercises 81

Computer Exercises 86

Biography of J. J. Sylvester 89

Supplementary Exercises for Chapters 1-4 91

5 Permutation Groups 95

Definition and Notation 95 $\,^{\circ}$ Cycle Notation 98 $\,^{\circ}$ Properties of Permutations 100 $\,^{\circ}$ A Check Digit Scheme Based on D_5 110 Exercises 113

Computer Exercises 118

Biography of Augustin Cauchy 121

6 Isomorphisms 122

Motivation 122 | Definition and Examples 122 | Cayley's

Theorem 126 | Properties of Isomorphisms 128 |

Automorphisms 129

Exercises 133

Computer Exercise 136

Biography of Arthur Caylev 137

7 Cosets and Lagrange's Theorem 138

Properties of Cosets 138 | Lagrange's Theorem and

Consequences 141 | An Application of Cosets to Permutation

Groups 145 | The Rotation Group of a Cube and a Soccer Ball 146

Exercises 149

Computer Exercise 153

Biography of Joseph Lagrange 154

8 External Direct Products 155

Definition and Examples 155 | Properties of External Direct

Products 156 | The Group of Units Modulo n as an External Direct

Product 159 | Applications 161

Exercises 167

Computer Exercises 170

Biography of Leonard Adleman 173

Supplementary Exercises for Chapters 5-8 174

9 Normal Subgroups and Factor Groups 178

Normal Subgroups 178 | Factor Groups 180 | Applications of Factor Groups †85 | Internal Direct Products 188

Exercises 193

Biography of Évariste Galois 199

10 Group Homomorphisms 200

Definition and Examples 200 | Properties of Homomorphisms 202 | The First Isomorphism Theorem 206

Exercises 211

Computer Exercise 216

Biography of Camille Jordan 217

11 Fundamental Theorem of Finite Abelian Groups 218

The Fundamental Theorem 218 | The Isomorphism Classes of Abelian Groups 218 | Proof of the Fundamental Theorem 223

Exercises 226

Computer Exercises 228

Supplementary Exercises for Chapters 9–11 230

PART3 Rings 235

12 Introduction to Rings 237

Motivation and Definition 237 | Examples of Rings 238 |

Properties of Rings 239 | Subrings 240

Exercises 242

Computer Exercises 245

Biography of I. N. Herstein 248

13 Integral Domains 249

Definition and Examples 249 | Fields 250 | Characteristic of a

Ring 252
Exercises 255

Computer Exercises 259

Biography of Nathan Jacobson 261

14 Ideals and Factor Rings 262

Ideals 262 | Factor Rings 263 | Prime Ideals and Maximal

Ideals 267

Exercises 269

Computer Exercises 273

Biography of Richard Dedekind 274

Biography of Emmy Noether 275

Supplementary Exercises for Chapters 12–14 276

15 Ring Homomorphisms 280

Definition and Examples 280 | Properties of Ring Homomorphisms 283 | The Field of Quotients 285

Exercises 287

16 Polynomial Rings 293

Biography of Serge Lang 321

Notation and Terminology 293 | The Division Algorithm and Consequences 296

Exercises 300

Biography of Saunders Mac Lane 304

17 Factorization of Polynomials 305

Reducibility Tests 305 | Irreducibility Tests 308 | Unique Factorization in Z[x] 313 | Weird Dice: An Application of Unique Factorization 314

Exercises 316

Computer Exercises 319

18 Divisibility in Integral Domains 322

Supplementary Exercises for Chapters 15–18 341

Irreducibles, Primes 322 | Historical Discussion of Fermat's Last
Theorem 325 | Unique Factorization Domains 328 | Euclidean
Domains 331

Exercises 335

Computer Exercise 337

Biography of Sophie Germain 339

Biography of Andrew Wiles 340

PART4 Fields 343

19 Vector Spaces 345

Definition and Examples 345 | Subspaces 346 | Linear Independence 347

Exercises 349
Biography of Emil Artin 352
Biography of Olga Taussky-Todd 353

20 Extension Fields 354

The Fundamental Theorem of Field Theory 354 | Splitting Fields 356 | Zeros of an Irreducible Polynomial 362 Exercises 366 | Biography of Leopold Kronecker 369

21 Algebraic Extensions 370

Characterization of Extensions 370 | Finite Extensions 372 |
Properties of Algebraic Extensions 376 |

Exercises 378

Biography of Irving Kaplansky 381

22 Finite Fields 382

Classification of Finite Fields 382 | Structure of Finite Fields 383 | Subfields of a Finite Field 387

Exercises 389

Computer Exercises 391

Biography of L. E. Dickson 392

23 Geometric Constructions 393

Historical Discussion of Geometric Constructions 393 Constructible Numbers 394 | Angle-Trisectors and Circle-Squarers 396 Exercises 396 Supplementary Exercises for Chapters 19–23 399

PART 5 Special Topics 401

24 Sylow Theorems 403

Conjugacy Classes 403 | The Class Equation 404 | The Probability That Two Elements Commute 405 | The Sylow Theorems 406 | Applications of Sylow Theorems 411

Exercises 414

Computer Exercise 418

Biography of Ludwig Sylow 419

25 Finite Simple Groups 420

Historical Background 420 | Nonsimplicity Tests 425 | The Simplicity of A_5 429 | The Fields Medal 430 | The Cole Prize 430 | Exercises 431 | Computer Exercises 432 | Biography of Michael Aschbacher 434 | Biography of Daniel Gorenstein 435

26 Generators and Relations 437

Biography of John Thompson 436

Motivation 437 | Definitions and Notation 438 | Free Group 439 | Generators and Relations 440 | Classification of Groups of Order Up to 15 444 | Characterization of Dihedral Groups 446 | Realizing the Dihedral Groups with Mirrors 447 Exercises 449

Biography of Marshall Hall, Jr. 452

27 Symmetry Groups 453

Isometries 453 | Classification of Finite Plane Symmetry Groups 455 | Classification of Finite Groups of Rotations in **R**³ 456 Exercises 458

28 Frieze Groups and Crystallographic Groups 461

The Frieze Groups 461 | The Crystallographic Groups 467 | Identification of Plane Periodic Patterns 473

Exercises 479

Biography of M. C. Escher 484

Biography of George Pólya 485 Biography of John H. Conway 486

29 Symmetry and Counting 487

Motivation 487 | Burnside's Theorem 488 | Applications 490 | Group Action 493

Exercises 494

Biography of William Burnside 497 30 Cayley Digraphs of Groups 498

Motivation 498 | The Cayley Digraph of a Group 498 | Hamiltonian Circuits and Paths 502 | Some Applications 508

Exercises 511
Biography of William Rowan Hamilton 516
Biography of Paul Erdös 517

31 Introduction to Algebraic Coding Theory 518

Motivation 518 | Linear Codes 523 | Parity-Check Matrix
Decoding 528 | Coset Decoding 531 | Historical Note: The
Ubiquitous Reed-Solomon Codes 535

Exercises 537

Biography of Richard W. Hamming 542

Biography of Jessie MacWilliams 543

Biography of Vera Pless 544

32 An Introduction to Galois Theory 545

Fundamental Theorem of Galois Theory 545 | Solvability of Polynomials by Radicals 552 | Insolvability of a Quintic 556 Exercises 557

Biography of Philip Hall 560

33 Cyclotomic Extensions 561

Motivation 561 | Cyclotomic Polynomials 562 |
The Constructible Regular n-gons 566

Exercises 568

Computer Exercise 569

Biography of Carl Friedrich Gauss 570

Biography of Manjul Bhargava 571

Supplementary Exercises for Chapters 24–33 572

Selected Answers A1

Text Credits A40

Photo Credits A42

Index of Mathematicians A43

Index of Terms A45