

- Preface p. XIII
- About the Authors p. XVII
- Part 1 Kinematics and Mechanisms p. 1
- 1 The World of Mechanisms p. 3
- 1.1 Introduction p. 3
- 1.2 Analysis and Synthesis p. 4
- 1.3 The Science of Mechanics p. 4
- 1.4 Terminology, Definitions, and Assumptions p. 5
- 1.5 Planar, Spherical, and Spatial Mechanisms p. 10
- 1.6 Mobility p. 11
- 1.7 Classification of Mechanisms p. 14
- 1.8 Kinematic Inversion p. 26
- 1.9 Grashof's Law p. 27
- 1.10 Mechanical Advantage p. 29
- Problems p. 31
- 2 Position and Displacement p. 33
- 2.1 Locus of a Moving Point p. 33
- 2.2 Position of a Point p. 36
- 2.3 Position Difference Between Two Points p. 37
- 2.4 Apparent Position of a Point p. 38
- 2.5 Absolute Position of a Point p. 39
- 2.6 The Loop-Closure Equation p. 41
- 2.7 Graphic Position Analysis p. 45
- 2.8 Algebraic Position Analysis p. 51
- 2.9 Complex-Algebra Solutions of Planar Vector Equations p. 55
- 2.10 Complex Polar Algebra p. 57
- 2.11 Position Analysis Techniques p. 60
- 2.12 The Chace Solutions to Planar Vector Equations p. 64
- 2.13 Coupler-Curve Generation p. 68
- 2.14 Displacement of a Moving Point p. 70
- 2.15 Displacement Difference Between Two Points p. 71
- 2.16 Rotation and Translation p. 72
- 2.17 Apparent Displacement p. 74
- 2.18 Absolute Displacement p. 75
- Problems p. 76
- 3 Velocity p. 79
- 3.1 Definition of Velocity p. 79
- 3.2 Rotation of a Rigid Body p. 80
- 3.3 Velocity Difference Between Points of a Rigid Body p. 82
- 3.4 Graphic Methods; Velocity Polygons p. 85
- 3.5 Apparent Velocity of a Point in a Moving Coordinate System p. 92
- 3.6 Apparent Angular Velocity p. 97
- 3.7 Direct Contact and Rolling Contact p. 98
- 3.8 Systematic Strategy for Velocity Analysis p. 99
- 3.9 Analytic Methods p. 100
- 3.10 Complex-Algebra Methods p. 101

- 3.11 The Method of Kinematic Coefficients p. 105
- 3.12 The Vector Method p. 116
- 3.13 Instantaneous Center of Velocity p. 117
- 3.14 The Aronhold-Kennedy Theorem of Three Centers p. 119
- 3.15 Locating Instant Centers of Velocity p. 120
- 3.16 Velocity Analysis Using Instant Centers p. 123
- 3.17 The Angular-Velocity-Ratio Theorem p. 126
- 3.18 Relationships Between First-Order Kinematic Coefficients and Instant Centers p. 127
- 3.19 Freudenstein's Theorem p. 129
- 3.20 Indices of Merit; Mechanical Advantage p. 130
- 3.21 Centrodes p. 133
 - Problems p. 135
- 4 Acceleration p. 141
 - 4.1 Definition of Acceleration p. 141
 - 4.2 Angular Acceleration p. 144
 - 4.3 Acceleration Difference Between Points of a Rigid Body p. 144
 - 4.4 Acceleration Polygons p. 151
 - 4.5 Apparent Acceleration of a Point in a Moving Coordinate System p. 155
 - 4.6 Apparent Angular Acceleration p. 163
 - 4.7 Direct Contact and Rolling Contact p. 164
 - 4.8 Systematic Strategy for Acceleration Analysis p. 167
 - 4.9 Analytic Methods p. 168
 - 4.10 Complex-Algebra Methods p. 169
 - 4.11 The Method of Kinematic Coefficients p. 171
 - 4.12 The Chace Solutions p. 175
 - 4.13 The Instant Center of Acceleration p. 177
 - 4.14 The Euler-Savary Equation p. 178
 - 4.15 The Bobillier Constructions p. 183
 - 4.16 Radius of Curvature of a Point Trajectory Using Kinematic Coefficients p. 187
 - 4.17 The Cubic of Stationary Curvature p. 188
 - Problems p. 190
 - Part 2 Design of Mechanisms p. 195
 - 5 Cam Design p. 197
 - 5.1 Introduction p. 197
 - 5.2 Classification of Cams and Followers p. 198
 - 5.3 Displacement Diagrams p. 200
 - 5.4 Graphical Layout of Cam Profiles p. 203
 - 5.5 Kinematic Coefficients of the Follower Motion p. 207
 - 5.6 High-Speed Cams p. 211
 - 5.7 Standard Cam Motions p. 212
 - 5.8 Matching Derivatives of the Displacement Diagrams p. 222
 - 5.9 Plate Cam with Reciprocating Flat-Face Follower p. 225
 - 5.10 Plate Cam with Reciprocating Roller Follower p. 230
 - Problems p. 250
 - 6 Spur Gears p. 252

- 6.1 Terminology and Definitions p. 252
- 6.2 Fundamental Law of Toothed Gearing p. 255
- 6.3 Involute Properties p. 256
- 6.4 Interchangeable Gears; AGMA Standards p. 257
- 6.5 Fundamentals of Gear-Tooth Action p. 259
- 6.6 The Manufacture of Gear Teeth p. 262
- 6.7 Interference and Undercutting p. 265
- 6.8 Contact Ratio p. 268
- 6.9 Varying the Center Distance p. 270
- 6.10 Involutometry p. 271
- 6.11 Nonstandard Gear Teeth p. 274
 - Problems p. 282
- 7 Helical Gears p. 286
 - 7.1 Parallel-Axis Helical Gears p. 286
 - 7.2 Helical Gear Tooth Relations p. 287
 - 7.3 Helical Gear Tooth Proportions p. 289
 - 7.4 Contact of Helical Gear Teeth p. 290
 - 7.5 Replacing Spur Gears with Helical Gears p. 291
 - 7.6 Herringbone Gears p. 292
 - 7.7 Crossed-Axis Helical Gears p. 292
 - Problems p. 295
- 8 Bevel Gears p. 297
 - 8.1 Straight-Tooth Bevel Gears p. 297
 - 8.2 Tooth Proportions for Bevel Gears p. 301
 - 8.3 Crown and Face Gears p. 302
 - 8.4 Spiral Bevel Gears p. 303
 - 8.5 Hypoid Gears p. 304
 - Problems p. 305
- 9 Worms and Worm Gears p. 306
 - 9.1 Basics p. 306
 - Problems p. 310
- 10 Mechanism Trains p. 311
 - 10.1 Parallel-Axis Gear Trains p. 311
 - 10.2 Examples of Gear Trains p. 313
 - 10.3 Determining Tooth Numbers p. 314
 - 10.4 Epicyclic Gear Trains p. 315
 - 10.5 Bevel Gear Epicyclic Trains p. 317
 - 10.6 Analysis of Planetary Gear Trains by Formula p. 317
 - 10.7 Tabular Analysis of Planetary Gear Trains p. 319
 - 10.8 Adders and Differentials p. 323
 - 10.9 All Wheel Drive Train p. 327
 - Problems p. 329
- 11 Synthesis of Linkages p. 332
 - 11.1 Type, Number, and Dimensional Synthesis p. 332
 - 11.2 Function Generation, Path Generation, and Body Guidance p. 333
 - 11.3 Two-Position Synthesis of Slider-Crank Mechanisms p. 333

- 11.4 Two-Position Synthesis of Crank-and-Rocker Mechanisms p. 334
- 11.5 Crank-Rocker Mechanisms with Optimum Transmission Angle p. 335
- 11.6 Three-Position Synthesis p. 338
- 11.7 Four-Position Synthesis; Point-Precision Reduction p. 339
- 11.8 Precision Positions; Structural Error; Chebychev Spacing p. 341
- 11.9 The Overlay Method p. 343
- 11.10 Coupler-Curve Synthesis p. 344
- 11.11 Cognate Linkages; The Roberts-Chebychev Theorem p. 348
- 11.12 Bloch's Method of Synthesis p. 350
- 11.13 Freudenstein's Equation p. 352
- 11.14 Analytic Synthesis Using Complex Algebra p. 356
- 11.15 Synthesis of Dwell Mechanisms p. 360
- 11.16 Intermittent Rotary Motion p. 361
- Problems p. 366
- 12 Spatial Mechanisms p. 368
- 12.1 Introduction p. 368
- 12.2 Exceptions in the Mobility of Mechanisms p. 369
- 12.3 The Position-Analysis Problem p. 373
- 12.4 Velocity and Acceleration Analyses p. 378
- 12.5 The Eulerian Angles p. 384
- 12.6 The Denavit-Hartenberg Parameters p. 387
- 12.7 Transformation-Matrix Position Analysis p. 389
- 12.8 Matrix Velocity and Acceleration Analyses p. 392
- 12.9 Generalized Mechanism Analysis Computer Programs p. 397
- Problems p. 400
- 13 Robotics p. 403
- 13.1 Introduction p. 403
- 13.2 Topological Arrangements of Robotic Arms p. 404
- 13.3 Forward Kinematics p. 407
- 13.4 Inverse Position Analysis p. 411
- 13.5 Inverse Velocity and Acceleration Analyses p. 414
- 13.6 Robot Actuator Force Analyses p. 418
- Problems p. 421
- Part 3 Dynamics of Machines p. 423
- 14 Static Force Analysis p. 425
- 14.1 Introduction p. 425
- 14.2 Newton's Laws p. 427
- 14.3 Systems of Units p. 428
- 14.4 Applied and Constraint Forces p. 429
- 14.5 Free-Body Diagrams p. 432
- 14.6 Conditions for Equilibrium p. 433
- 14.7 Two- and Three-Force Members p. 435
- 14.8 Four-Force Members p. 443
- 14.9 Friction-Force Models p. 445
- 14.10 Static Force Analysis with Friction p. 448
- 14.11 Spur- and Helical-Gear Force Analysis p. 451

- 14.12 Straight-Bevel-Gear Force Analysis p. 457
- 14.13 The Method of Virtual Work p. 461
- Problems p. 464
- 15 Dynamic Force Analysis (Planar) p. 470
- 15.1 Introduction p. 470
- 15.2 Centroid and Center of Mass p. 470
- 15.3 Mass Moments and Products of Inertia p. 475
- 15.4 Inertia Forces and D'Alembert's Principle p. 478
- 15.5 The Principle of Superposition p. 485
- 15.6 Planar Rotation About a Fixed Center p. 489
- 15.7 Shaking Forces and Moments p. 492
- 15.8 Complex Algebra Approach p. 492
- 15.9 Equation of Motion p. 502
- Problems p. 511
- 16 Dynamic Force Analysis (Spatial) p. 515
- 16.1 Introduction p. 515
- 16.2 Measuring Mass Moment of Inertia p. 515
- 16.3 Transformation of Inertia Axes p. 519
- 16.4 Euler's Equations of Motion p. 523
- 16.5 Impulse and Momentum p. 527
- 16.6 Angular Impulse and Angular Momentum p. 528
- Problems p. 538
- 17 Vibration Analysis p. 542
- 17.1 Differential Equations of Motion p. 542
- 17.2 A Vertical Model p. 546
- 17.3 Solution of the Differential Equation p. 547
- 17.4 Step Input Forcing p. 551
- 17.5 Phase-Plane Representation p. 553
- 17.6 Phase-Plane Analysis p. 555
- 17.7 Transient Disturbances p. 559
- 17.8 Free Vibration with Viscous Damping p. 563
- 17.9 Damping Obtained by Experiment p. 565
- 17.10 Phase-Plane Representation of Damped Vibration p. 567
- 17.11 Response to Periodic Forcing p. 571
- 17.12 Harmonic Forcing p. 574
- 17.13 Forcing Caused by Unbalance p. 579
- 17.14 Relative Motion p. 580
- 17.15 Isolation p. 580
- 17.16 Rayleigh's Method p. 583
- 17.17 First and Second Critical Speeds of a Shaft p. 586
- 17.18 Torsional Systems p. 592
- Problems p. 594
- 18 Dynamics of Reciprocating Engines p. 598
- 18.1 Engine Types p. 598
- 18.2 Indicator Diagrams p. 603
- 18.3 Dynamic Analysis--General p. 606

- 18.4 Gas Forces p. 606
- 18.5 Equivalent Masses p. 609
- 18.6 Inertia Forces p. 610
- 18.7 Bearing Loads in a Single-Cylinder Engine p. 613
- 18.8 Crankshaft Torque p. 616
- 18.9 Engine Shaking Forces p. 616
- 18.10 Computation Hints p. 617
- Problems p. 620
- 19 Balancing p. 621
- 19.1 Static Unbalance p. 621
- 19.2 Equations of Motion p. 622
- 19.3 Static Balancing Machines p. 624
- 19.4 Dynamic Unbalance p. 626
- 19.5 Analysis of Unbalance p. 627
- 19.6 Dynamic Balancing p. 635
- 19.7 Balancing Machines p. 638
- 19.8 Field Balancing with a Programmable Calculator p. 640
- 19.9 Balancing a Single-Cylinder Engine p. 643
- 19.10 Balancing Multicylinder Engines p. 647
- 19.11 Analytical Technique for Balancing Multicylinder Reciprocating Engines p. 651
- 19.12 Balancing Linkages p. 656
- 19.13 Balancing of Machines p. 661
- Problems p. 663
- 20 Cam Dynamics p. 665
- 20.1 Rigid- and Elastic-Body Cam Systems p. 665
- 20.2 Analysis of an Eccentric Cam p. 666
- 20.3 Effect of Sliding Friction p. 670
- 20.4 Analysis of Disk Cam with Reciprocating Roller Follower p. 671
- 20.5 Analysis of Elastic Cam Systems p. 673
- 20.6 Unbalance, Spring Surge, and Windup p. 675
- Problems p. 676
- 21 Flywheels p. 678
- 21.1 Dynamic Theory p. 678
- 21.2 Integration Technique p. 680
- 21.3 Multicylinder Engine Torque Summation p. 682
- Problems p. 683
- 22 Governors p. 685
- 22.1 Classification p. 685
- 22.2 Centrifugal Governors p. 686
- 22.3 Inertia Governors p. 687
- 22.4 Mechanical Control Systems p. 687
- 22.5 Standard Input Functions p. 689
- 22.6 Solution of Linear Differential Equations p. 690
- 22.7 Analysis of Proportional-Error Feedback Systems p. 695
- 23 Gyroscopes p. 699
- 23.1 Introduction p. 699

- 23.2 The Motion of a Gyroscope p. 700
- 23.3 Steady or Regular Precession p. 701
- 23.4 Forced Precession p. 704
- Problems p. 711
- Appendixes
- Appendix A Tables
- Table 1 Standard SI Prefixes p. 712
- Table 2 Conversion from U.S. Customary Units to SI Units p. 713
- Table 3 Conversion from SI Units to U.S. Customary Units p. 713
- Table 4 Properties of Areas p. 714
- Table 5 Mass Moments of Inertia p. 715
- Table 6 Involute Function p. 716
- Appendix B Answers to Selected Problems p. 718
- Index p. 725