
Contents

Preface.....	xiii
Authors.....	xvii
Chapter 1 Introduction to Kinematics.....	1
1.1 Kinematics.....	1
1.2 Kinematic Chains and Mechanisms.....	2
1.3 Mobility, Planar and Spatial Mechanisms.....	3
1.4 Types of Mechanism Motion.....	4
1.5 Kinematic Synthesis.....	6
1.6 Units and Conversions.....	7
1.7 Software Resources	8
1.8 Summary	8
References	9
Additional Reading	9
Chapter 2 Mathematical Concepts in Kinematics	11
2.1 Introduction	11
2.2 Complex Numbers and Operations	11
2.2.1 Complex Number Forms	11
2.2.2 Complex Number Addition	13
2.2.3 Complex Number Multiplication and Differentiation.....	15
2.3 Vector and Point Representation	18
2.4 Linear Simultaneous Equations, Matrices, and Matrix Operations.....	19
2.4.1 Linear Simultaneous Equation Systems and Matrices.....	19
2.4.2 Matrix Transpose, Addition, Subtraction, and Multiplication	21
2.4.3 The Identity Matrix and Matrix Inversion	24
2.5 Intermediate and Total Spatial Motion.....	26
2.6 General Transformation Matrix	30
2.7 Summary	33
References	33
Additional Reading	33
Chapter 3 Fundamental Concepts in Kinematics	37
3.1 Types of Planar and Spatial Mechanisms.....	37
3.1.1 Planar Four-Bar Mechanism	37
3.1.2 Slider-Crank Mechanism	37
3.1.3 Geared Five-Bar Mechanism	37
3.1.4 Planar Multiloop Six-Bar Mechanisms	39
3.1.5 Spatial Four-Bar Mechanisms	40
3.2 Links, Joints, and Mechanism Mobility	41
3.3 Number Synthesis.....	44
3.4 Grashof's Criteria and Transmission Angle	45
3.5 Circuit Defect	48
3.6 Mechanism Inversion	48

3.7	Passive Degree of Freedom and Paradoxes	49
3.8	Summary	50
	References	51
Chapter 4	Kinematic Analysis of Planar Mechanisms	55
4.1	Introduction	55
4.2	Numerical Solution Method for Two Simultaneous Equations	56
4.3	Link Velocity and Acceleration Components in Planar Space.....	57
4.4	Four-Bar Mechanism Analysis.....	58
4.4.1	Displacement Equations	58
4.4.2	Velocity Equations	58
4.4.3	Acceleration Equations.....	60
4.4.4	Kinematics of Coupler Locations of Interest	61
4.4.5	Instant Center, Centrodes, and Centrede Generation.....	66
4.5	Slider-Crank Mechanism Analysis.....	70
4.5.1	Displacement Equations	70
4.5.2	Velocity Equations	71
4.5.3	Acceleration Equations.....	73
4.5.4	Centrede Generation	78
4.6	Geared Five-Bar Mechanism Analysis.....	79
4.6.1	Displacement Equations	79
4.6.2	Velocity Equations	80
4.6.3	Acceleration Equations.....	82
4.6.4	Kinematics of Intermediate Link Locations of Interest.....	83
4.7	Watt II Mechanism Analysis	86
4.8	Stephenson III Mechanism Analysis	89
4.8.1	Displacement Equations	89
4.8.2	Velocity Equations	91
4.8.3	Acceleration Equations.....	92
4.8.4	Kinematics of Intermediate Link Locations of Interest.....	93
4.9	Time and Driver Angular Velocity.....	95
4.10	Mechanism Configurations	96
4.11	Constructing Cognates	97
4.12	Planar Mechanism Kinematic Analysis and Modeling in SimMechanics®	99
4.13	Summary	102
	References	103
	Additional Reading	103
Chapter 5	Dimensional Synthesis	115
5.1	Introduction	115
5.2	Branch and Order Defects	117
5.3	Planar Four-Bar Motion Generation: Three Precision Positions.....	118
5.4	Order- and Branch-Defect Elimination	123
5.5	Path Generation versus Motion Generation.....	127
5.6	Stephenson III Motion Generation: Three Precision Positions	127
5.7	Planar Four-Bar Function Generation: Three Precision Points.....	131
5.8	Planar Four-Bar Function Generation: FSPs and MSPs.....	135
5.9	Mechanism Dimensions: From Dimensional Synthesis to Kinematic Analysis	138

5.10	Summary	141
References	142	
Additional Reading	143	
Chapter 6	Static Force Analysis of Planar Mechanisms.....	151
6.1	Introduction	151
6.2	Static Loading in Planar Space	152
6.3	Four-Bar Mechanism Analysis.....	153
6.4	Slider-Crank Mechanism Analysis.....	156
6.5	Geared Five-Bar Mechanism Analysis.....	158
6.6	Watt II Mechanism Analysis	162
6.7	Stephenson III Mechanism Analysis.....	166
6.8	Planar Mechanism Static Force Analysis and Modeling in SimMechanics® ..	170
6.9	Summary	171
References	172	
Additional Reading	172	
Chapter 7	Dynamic Force Analysis of Planar Mechanisms.....	185
7.1	Introduction	185
7.2	Dynamic Loading in Planar Space.....	185
7.3	Four-Bar Mechanism Analysis.....	186
7.4	Slider-Crank Mechanism Analysis.....	190
7.5	Geared Five-Bar Mechanism Analysis.....	194
7.6	Watt II Mechanism Analysis	198
7.7	Stephenson III Mechanism Analysis.....	203
7.8	Mass Moment of Inertia and Computer-Aided Design Software	207
7.9	Planar Mechanism Dynamic Force Analysis and Modeling in SimMechanics®	208
7.10	Summary	210
References	211	
Additional Reading	211	
Chapter 8	Design and Kinematic Analysis of Gears	227
8.1	Introduction	227
8.2	Gear Types.....	228
8.3	Spur-Gear Nomenclature and Relationships of Mating Gears.....	230
8.3.1	Spur-Gear Nomenclature.....	230
8.3.2	Pressure Angle and Involute Tooth Profile	233
8.3.3	Gear Center Distance and Contact Ratio	234
8.3.4	Gear-Tooth Interference and Undercutting	237
8.3.5	Backlash	238
8.4	Helical-Gear Nomenclature.....	239
8.5	Gear Kinematics.....	242
8.5.1	Spur Gears and Gear Trains.....	242
8.5.2	Planetary Gear Trains	246
8.5.3	Rack and Pinion Gears.....	249
8.5.4	Helical Gears.....	250
8.5.5	Bevel Gears	252

8.5.6 Worm Gears	253
8.6 Summary	256
References	257
Additional Reading	257
Chapter 9 Design and Kinematic Analysis of Disk Cams.....	261
9.1 Introduction	261
9.2 Follower Types	261
9.3 Follower Motion	263
9.3.1 Rise, Fall, and Dwell	263
9.3.2 Displacement, Velocity, Acceleration, and Jerk	264
9.3.3 Constant Velocity Motion.....	264
9.3.4 Constant Acceleration Motion.....	267
9.3.5 Simple Harmonic Motion.....	269
9.3.6 Cycloidal Motion.....	271
9.3.7 Polynomial Motion.....	274
9.4 Disk Cam Design and Pressure Angle	280
9.5 Summary	284
References	285
Additional Reading	285
Chapter 10 Kinematic Analysis of Spatial Mechanisms	291
10.1 Introduction	291
10.2 RRSS Mechanism Analysis.....	291
10.2.1 Displacement Equations	291
10.2.2 Velocity Equations	293
10.2.3 Acceleration Equations.....	295
10.3 RSSR Mechanism Analysis.....	297
10.3.1 Displacement Equations	297
10.3.2 Velocity Equations	299
10.3.3 Acceleration Equations.....	299
10.4 Four-Revolute Spherical Mechanism Analysis	302
10.5 Planar Four-Bar Kinematic Analysis Using RRSS and RSSR Kinematic Equations	305
10.6 Spatial Mechanism Kinematic Analysis and Modeling in SimMechanics®	307
10.7 Summary	308
References	308
Chapter 11 Introduction to Robotic Manipulators.....	315
11.1 Introduction	315
11.2 Terminology and Nomenclature.....	316
11.3 Robotic Manipulator Mobility and Types	317
11.4 The General Transformation Matrix	319
11.5 Forward Kinematics	322
11.5.1 Definition and Application	322
11.5.2 P-P-P.....	322
11.5.3 R-P-P	324

11.5.4 R-R-P	326
11.5.5 R-R-R	328
11.5.6 R-R-C	330
11.6 Inverse Kinematics	332
11.6.1 Definition and Application	332
11.6.2 P-P-P	332
11.6.3 R-P-P	334
11.6.4 R-R-P	336
11.6.5 R-R-R	338
11.6.6 R-R-C	339
11.7 Robotic Manipulator Kinematic Analysis and Modeling in SimMechanics®	341
11.8 Summary	342
References	342
Additional Reading	342
Appendix A	347
Appendix B	351
Appendix C	361
Appendix D	369
Appendix E	381
Appendix F	387
Appendix G	391
Appendix H	397
Appendix I	407
Appendix J	417
Appendix K	429
Appendix L	433
Index	437