

Contents

1	Introduction	1
1.1	Degrees of Freedom and Motion	1
1.2	Kinematic Pairs	3
1.3	Dyads	8
1.4	Independent Contours	10
1.5	Planar Mechanism Decomposition	10
2	Position Analysis	15
2.1	Absolute Cartesian Method	15
2.2	Slider-Crank (R-RRT) Mechanism	16
2.3	Four-Bar (R-RRR) Mechanism	20
2.4	R-RTR-RTR Mechanism	27
2.5	R-RTR-RTR Mechanism: Complete Rotation	31
2.5.1	Method I: Constraint Conditions	31
2.5.2	Method II: Euclidian Distance Function	35
2.6	Path of a Point on a Link with General Plane Motion	37
2.7	Creating a Movie	40
3	Velocity and Acceleration Analysis	43
3.1	Introduction	43
3.2	Velocity Field for a Rigid Body	44
3.3	Acceleration Field for a Rigid Body	46
3.4	Motion of a Point that Moves Relative to a Rigid Body	50
3.5	Slider-Crank (R-RRT) Mechanism	53
3.6	Four-Bar (R-RRR) Mechanism	60
3.7	Inverted Slider-Crank Mechanism	65
3.8	R-RTR-RTR Mechanism	71
3.9	Derivative Method	79
3.10	Independent Contour Equations	95

4	Dynamic Force Analysis	109
4.1	Equation of Motion for General Planar Motion	109
4.2	D'Alembert's Principle	114
4.3	Free-Body Diagrams	115
4.4	Force Analysis Using Dyads	116
4.4.1	RRR Dyad	116
4.4.2	RRT Dyad	118
4.4.3	RTR Dyad	119
4.5	Force Analysis Using Contour Method	120
4.6	Slider-Crank (R-RRT) Mechanism	121
4.6.1	Inertia Forces and Moments	124
4.6.2	Joint Forces and Drive Moment	126
4.7	R-RTR-RTR Mechanism	147
4.7.1	Inertia Forces and Moments	151
4.7.2	Joint Forces and Drive Moment	154
5	Direct Dynamics: Newton–Euler Equations of Motion	183
5.1	Compound Pendulum	183
5.2	Double Pendulum	192
5.3	One-Link Planar Robot Arm	201
5.4	Two-Link Planar Robot Arm	204
6	Analytical Dynamics of Open Kinematic Chains	209
6.1	Generalized Coordinates and Constraints	209
6.2	Laws of Motion	211
6.3	Lagrange's Equations for Two-Link Robot Arm	213
6.4	Rotation Transformation	225
6.5	RRT Robot Arm	228
6.5.1	Direct Dynamics	228
6.5.2	Inverse Dynamics	246
6.5.3	Kane's Dynamical Equations	250
6.6	RRTR Robot Arm	257
7	Problems	275
7.1	Problem Set: Mechanisms	275
7.2	Problem Set: Robots	291
A	Programs of Chapter 2: Position Analysis	301
A.1	Slider-Crank (R-RRT) Mechanism	301
A.2	Four-Bar (R-RRR) Mechanism	303
A.3	R-RTR-RTR Mechanism	306
A.4	R-RTR-RTR Mechanism: Complete Rotation	309
A.5	R-RTR-RTR Mechanism: Complete Rotation Using Euclidian Distance Function	312
A.6	Path of a Point on a Link with General Plane Motion: R-RRT Mechanism	314

A.7	Path of a Point on a Link with General Plane Motion: R-RRR Mechanism	315
B	Programs of Chapter 3: Velocity and Acceleration Analysis	317
B.1	Slider-Crank (R-RRT) Mechanism	317
B.2	Four-Bar (R-RRR) Mechanism	322
B.3	Inverted Slider-Crank Mechanism	326
B.4	R-RTR-RTR Mechanism	331
B.5	R-RTR-RTR Mechanism: Derivative Method	339
B.6	Inverted Slider-Crank Mechanism: Derivative Method	344
B.7	R-RTR Mechanism: Derivative Method	347
B.8	R-RRR Mechanism: Derivative Method	349
B.9	R-RTR-RTR Mechanism: Contour Method	354
C	Programs of Chapter 4: Dynamic Force Analysis	363
C.1	Slider-Crank (R-RRT) Mechanism: Newton–Euler Method	363
C.2	Slider-Crank (R-RRT) Mechanism: D’Alembert’s Principle	368
C.3	Slider-Crank (R-RRT) Mechanism: Dyad Method	372
C.4	Slider-Crank (R-RRT) Mechanism: Contour Method	378
C.5	R-RTR-RTR Mechanism: Newton–Euler Method	382
C.6	R-RTR-RTR Mechanism: Dyad Method	396
C.7	R-RTR-RTR Mechanism: Contour Method	408
D	Programs of Chapter 5: Direct Dynamics	423
D.1	Compound Pendulum	423
D.2	Compound Pendulum Using the Function $R(t, x)$	425
D.3	Double Pendulum	426
D.4	Double Pendulum Using the File <code>RR.m</code>	428
D.5	One-Link Planar Robot Arm	430
D.6	One-Link Planar Robot Arm Using the m-File Function <code>Rrobot.m</code>	432
D.7	Two-Link Planar Robot Arm Using the m-File Function <code>RRrobot.m</code>	433
E	Programs of Chapter 6: Analytical Dynamics	437
E.1	Lagrange’s Equations for Two-Link Robot Arm	437
E.2	Two-Link Robot Arm: Inverse Dynamics	442
E.3	RRT Robot Arm	444
E.4	RRT Robot Arm: Inverse Dynamics	453
E.5	RRT Robot Arm: Kane’s Dynamical Equations	457
E.6	RRTR Robot Arm	462
	References	475
	Index	477