

Contents

1. MATHEMATICAL PRELIMINARIES	1
1.0 Introduction	1
1.1 Vector space, linear dependence and basis of a vector space	1
1.2 Linear transformation and its matrix representation	3
1.3 Range and null space of a linear transformation	7
1.4 Eigenvalues and eigenvectors of a linear transformation	7
1.5 Change of basis	9
1.6 Diagonalization of matrices	12
1.7 Bilinear forms and sign definition of matrices	14
1.8 Norms, isometries, orthogonal and unitary matrices	20
1.9 Properties of unitary and orthogonal matrices	21
1.10 Stationary points of scalar functions of a vector argument	22
1.11 Linear algebraic systems	25
1.12 Numerical solution of linear algebraic systems	29
1.13 Numerical solution of nonlinear algebraic systems	33
References	56
2. FUNDAMENTALS OF RIGID-BODY THREE-DIMENSIONAL KINEMATICS	57
2.1 Introduction	57
2.2 Motion of a rigid body	57
2.3 The Theorem of Euler and the revolute matrix	61
2.4 Groups of rotations	76
2.5 Rodrigues' formula and the cartesian decomposition of the rotation matrix	80
2.6 General motion of a rigid body and Chasles' Theorem	85
2.7 Velocity of a point of a rigid body rotating about a fixed point	119
2.8 Velocity of a moving point referred to a moving observer	124
2.9 General motion of a rigid body	126

2.10 Theorems related to the velocity distribution in a moving rigid body	149
2.11 Acceleration distribution in a rigid body moving about a fixed point	157
2.12 Acceleration distribution in a rigid body under general motion	159
2.13 Acceleration of a moving point referred to a moving observer	163
References	166
3. GENERALITIES ON LOWER-PAIR KINEMATIC CHAINS	
3.1 Introduction	167
3.2 Kinematic pairs	167
3.3 Degree of freedom	168
3.4 Classification of lower pairs	168
3.5 Classification of kinematic chains	176
3.6 Linkage problems in the Theory of Machines and Mechanisms	186
References	188
4. ANALYSIS OF MOTIONS OF KINEMATIC CHAINS	
4.1 Introduction	189
4.2 The method of Denavit and Hartenberg	189
4.3 An alternate method of analysis	208
4.4 Applications to open kinematic chains	215
References	218
5. SYNTHESIS OF LINKAGES	
5.1 Introduction	219
5.2 Synthesis for function generation	219
5.3 Mechanism synthesis for rigid-body guidance	246
5.4 A different approach to the synthesis problem for rigid-body guidance	270
5.5 Linkage synthesis for path generation	284
5.6 Epilogue	291
References	292

6. AN INTRODUCTION TO THE OPTIMAL SYNTHESIS OF LINKAGES	294
6.1 Introduction	294
6.2 The optimisation problem	295
6.3 Overdetermined problems of linkage synthesis	296
6.4 Underdetermined problems of linkage synthesis subject to no inequality constraints	309
6.5 Linkage optimisation subject to inequality constraints. Penalty function methods	321
6.6 Linkage optimisation subject to inequality constraints. Direct methods	332
References	352
Appendix 1 Algebra of dyadics	354
Appendix 2 Derivative of a determinant with respect to a scalar argument	357
Appendix 3 Computation of $\epsilon_{ijk}\epsilon_{lmn}$	360
Appendix 4 Synthesis of plane linkages for rigid- body guidance	362
Subject Index	364