## **Contents**

СНАРТ	TER 1	
Concept	ts from Linear System Theory	1
1.1	Introduction	1
1.2	Concepts from System Analysis	1
1.3	Classification of Systems. Superposition Principle	5
1.4	System Differential Equation	7
1.5	System Response	9
1.6	Impedance Function and Frequency Response	10
1.7	Transfer Function	14
1.8	Singularity Functions	16
1.9	Impulse Response	20
	Step Response	21 23
1.11	, , , , , , , , , , , , , , , , , , ,	23 26
1.12	State Equations Problems	20
	Problems	21
СНАРТ	<del></del>	
Kinema	tics	31
2.1	Introduction	31
2.2	Motion Relative to a Fixed Reference Frame. Cartesian Components	31
2.3	Planar Motion in Terms of Curvilinear Coordinates	36
2.4	Moving Reference Frames	41
2.5	Planar Motion of Rigid Bodies	49
2.6	General Case of Motion	55
	Problems	58
СНАРТ	TER 3	
Dynami	ics of a Particle	63
3.1	Introduction	63
3.2	Newton's Laws	64
3.3	Integration of the Equations of Motion	66
3.4	Impulse and Momentum	71
3.5	Moment of a Force and Angular Momentum about a Fixed Point	73
3.6	Work and Energy	75
3.7	Motion in a Central-Force Field	80
3.8	The Inverse Square Law. Orbits of Planets and Satellites	82
	Problems	89
		хi

## xii Contents

Kespons	e of First-Order and Second-Order Systems	93
4.1	Introduction	93
4.2	Differential Equations of Motion for Mechanical Systems	94
4.3	Differential Equations for Electrical Systems	98
4.4	Free Response of First-Order Systems	101
4.5	Free Response of Undamped Second-Order Systems. The Harmonic	
	Oscillator	103
4.6	Free Response of Damped Second-Order Systems	107
4.7	The Logarithmic Decrement	112
4.8	Response of First-Order Systems to Harmonic Excitation. Frequency	445
4.9	Response	115
4.10	Response of Second-Order Systems to Harmonic Excitation	117 122
4.11	Geometric Interpretation of the Response to Harmonic Excitation Rotating Unbalanced Masses	123
4.12	_	126
4.13	· · · · · · · · · · · · · · · · · · ·	129
4.14	1	131
4.15	Response to Arbitrary Excitation	132
	Problems	134
CHAPT Dynami	ER 5 ics of Systems of Particles	141
5.1	Introduction	141
5.2	The Equation of Motion for a System of Particles	141
5.3	Equation of Motion in Terms of the Mass Center	143
5.4	Linear Momentum	144
5.5	Angular Momentum	146
5.6	Kinetic Energy	150
5.7	The Two-Body Problem	151
5.8	Variable-Mass Systems. Rocket Motion Problems	154 157
CHAPT Dynami	ER 6 cs of Rigid Bodies	161
6.1	Introduction	161
6.2	Linear and Angular Momentum	161
6.3	The Equations of Motion	164
6.4	Kinetic Energy	166
6.5	Planar Motion of a Rigid Body	167
6.6	Rotation of a Rigid Body about a Fixed Axis	173
6.7	Systems of Rigid Bodies	176
6.8	Motion of a Torque-Free Symmetric Body	178
6.9	Rotation about a Fixed Point. Gyroscopes	181
6.10	Small Oscillations About Steady Precession	185
	Problems	189

CHAPT		400
Elemen	ts of Analytical Dynamics	197
7.1	Introduction	19
7.2	Generalized Coordinates	198
7.3	The Principle of Virtual Work	199
7.4	D'Alembert's Principle	204
7.5	Lagrange's Equations of Motion	200
	Problems	211
CHAPT	TER 8	
	on of Linear Multi-Degree-of-Freedom Systems	213
8.1	Introduction	213
8.2	Lagrange's Equations of Motion for Linear Systems	213
8.3	Normal-Mode Vibration. The Eigenvalue Problem	219
8.4	Orthogonality of the Modal Vectors	225
8.5	Response of Multi-Degree-of-Freedom Undamped Systems by Modal	
	Analysis	229
8.6	Damped Systems	235
	Problems	239
CHAPT	TER 9	
Introdu	ction to System Stability	243
9.1	Introduction	243
9.2	Motion in the Phase Plane	243
9.3	Stability of Equilibrium Points	246
9.4	Motion in the Neighborhood of Equilibrium Points	247
9.5	Conservative Systems	252
9.6	Motion in the State Space	254
9.7	Routh-Hurwitz Criterion	261
	Problems	265
СНАРТ	ER 10	
Comput	ational Techniques for the Response	269
10.1	Introduction	269
10.2	Solution of the State Equations for Linear Systems by the Transition  Matrix	270
10.3		
10.3 10.4	Computational Aspects of the Response by the Transition Matrix Response of General Damped Systems by the Transition Matrix	276
		280
10.5	Discrete-Time Systems. The Convolution Sum	282
10.6	Discrete-Time Solution of the State Equations	287
10.7	Stability of Discrete-Time Systems	291
10.8	Euler's Method	293
10.9	The Runge-Kutta Methods	295

## Xiv Contents

Index

Feedbac	k Control Systems	301
11.1	Introduction	301
11.2	Feedback Control Systems	301
11.3	Performance of Control Systems	304
11.4	The Root-Locus Method	308
11.5	The Method of Nyquist	323
11.6	Bode Diagrams	331
11.7	Position Servomechanism	341
11.8	Relative Stability. Gain Margin and Phase Margin	345
11.9	Compensators	349
11.10	Derivation of the System Response from the Transfer Function	356
11.11	Feedback Control of Multivariable Systems	360
11.12	Modal Control	362
	Problems	369
Append	ix	373
<b>A.1</b>	Definitions	373
A.2	Transformation of Derivatives	373
<b>A.3</b>	The Inverse Laplace Transformation	374
A.4	First and Second Shifting Theorems	377
A.5	Initial- and Final-Value Theorems	378
A.6	The Convolution Integral	379
<b>A.7</b>	Table of Laplace Transform Pairs	381
Bibliog	raphy	383

385