

Mechanical Engineering Series

TABLE OF CONTENTS

Chapter 1	2.3 Equivalent Systems Method 72
INTRODUCTION I	2.4 Free Vibrations of Undamped
MINODOCITON I	One-Degree-of-Freedom Systems 79
1.1 The Study of Vibrations 1	2.5 Free Vibrations of One-Degree-of-Freedom
1.2 Mathematical Modeling 3	Systems with Viscous Damping 87
1.2.1 Problem Identification 3	2.6 Coulomb Damping 103
1.2.2 Assumptions 3	2.7 Hysteretic Damping 110
1.2.3 Basic Laws of Nature 4	2.8 Other Forms of Damping 115
1.2.4 Constitutive Equations 5	Problems 117
1.2.5 Geometric Constraints 5	MATLAB Problems 129
1.2.6 Mathematical Solution 5	
1.2.7 Physical Interpretation of Results 5	Chapter 3
1.3 Generalized Coordinates 6	HARMONIC EXCITATION OF ONE-
1.4 Review of Dynamics 8	T
1.4.1 Kinematics 9	DEGREE-OF-FREEDOM SYSTEMS 131
1.4.2 Basic Principles of Rigid-Body Kinetics	3.1 Introduction '131
for Planar Motion 11	3.2 Differential Equations Governing Forced
1.4.3 Principle of Work-Energy 14	Vibrations 132
1.4.4 Principle of Impulse and	3.3 Forced Response of an Undamped System
Momentum 18	Due to a Single-Frequency Excitation 135
1.5 Classification of Vibration 18	3.4 Forced Response of a Viscously Damped
1.6 Springs 19	System Subject to a Single-Frequency
1.6.1 Introduction 19	Harmonic Excitation 138
1.6.2 Helical Coil Springs 21	3.5 Frequency-Squared Excitations 145
1.6.3 Elastic Elements as Springs 23	3.5.1 General Theory 145
1.6.4 Springs in Combination 25	3.5.1 General Theory 143 3.5.2 Rotating Unbalance 148
1.6.5 Inertia Effects of Springs 30	3.5.3 Vortex Shedding from Circular
1.7 Viscous Dampers 34	Cylinders 150
1.8 Floating and Immersed Bodies 37	3.6 Response Due to Harmonic Excitation
1.8.1 Buoyancy 37 1.8.2 Added Mass 38	of Support 155
	3.7 Systems with Coulomb Damping 163
1.9 Summary 40 Problems 41	3.8 Systems with Hysteretic Damping 167
MATLAB Problems 59	3.9 Multifrequency Excitations 170
WAILAB Problems 39	3.10 Fourier Series Representation of Periodic
Chapter 2	Functions 173
•	3.11 Seismic Vibration-Measuring
FREE VIBRATIONS OF ONE-DEGREE-	Instruments 176
OF-FREEDOM SYSTEMS 61	
2.1 Introduction 61	3.12 Complex Representations 181 Problems 184
2.2 Free-Body Diagram Method 62	
2.2 Tree-body Diagram Method 02	MATLAB Problems 195

Chapter 4	6.3 Natural Frequencies and Mode Shapes 297
TRANSIENT VIBRATIONS OF ONE-	6.4 General Solution 312
DEGREE-OF-FREEDOM SYSTEMS 199	6.5 Special Cases 313
DEGREE OF TREEDOM STOTEM 199	6.6 Energy Scalar Products 320
4.1 Introduction 199	6.7 Properties of Natural Frequencies and Mode
4.2 Derivation of Convolution Integral 201	Shapes 322
4.2.3 Response Due to a Unit Impulse 201	6.8 Normalized Mode Shapes 325
4.2.4 Response Due to a General	6.9 Rayleigh's Quotient 327
Excitation 202	6.10 Principal Coordinates 329
4.3 Excitations Whose Forms Change at Discrete	6.11 Determination of Natural Frequencies
Times 205	and Mode Shapes 332
4.4 Transient Motion Due to Base	6.12 Proportional Damping 339
Excitation 212	6.13 General Viscous Damping 341
4.5 Laplace Transform Solutions 216	Problems 346
4.6 Shock Spectrum 222	MATLAB Problems 352
4.7 Numerical Methods 225	MAILAB Problems 552
4.7.1 Numerical Evaluation of Convolution	Chapter 7
Integral 225	-
4.7.2 Numerical Solution of Eq. (4.1) 229	FORCED VIBRATIONS OF MULTI-
Problems 236	DEGREE-OF-FREEDOM SYSTEMS 355
MATLAB Problems 241	7.1 Total destina 255
	7.1 Introduction 355
Chapter 5	7.2 Harmonic Excitations 356
Multi-Degree-of-Freedom	7.3 Laplace Transform Solutions 361
	7.4 Modal Analysis for Undamped Systems
Systems: Derivation	and Systems with Proportional Damping 365
of Governing Equations 247	7.5 Modal Analysis for Systems
51 7 4 1 2 047	with General Damping 377
5.1 Introduction 247	7.6 Numerical Solutions 381
5.2 Derivation of Differential Equations by Using	Problems 388
Basic Principles of Dynamics 249	MATLAB Problems 391
5.3 Lagrange's Equations 252	
5.4 Matrix Formulation of Differential Equations	Chapter 8
for Linear Systems 258	
5.5 Stiffness Influence Coefficients 263	VIBRATION CONTROL 397
5.6 Flexibility Influence Coefficients 272	8.1 Introduction 397
5.7 Lumped-Mass Modeling of Continuous	8.2 Vibration Isolation Theory 400
Systems 279	8.3 Vibration Isolation Theory for Harmonic
Problems 282	Excitation 402
MATLAB Problems 292	8 3.1 General Theory 402
	8.3.2 Frequency-Squared Excitation 406
Chapter 6	8.3.3 Multifrequency and General Periodic
FREE VIBRATIONS OF MULTI-	Excitations 410
	8.4 Practical Aspects of Vibration Analysis 412
DEGREE-OF-FREEDOM SYSTEMS 295	8.5 Shock Isolation 418
6.1 Introduction 295	8.5.1 Short-Duration Pulses 418
6.2 Normal-Mode Solution 295	8.5.2 Long-Duration Pulses 421
0.2 1 William Mode Boldwolf 2/2	0.5.2 Eving Datation 1 alove 721

x

8.6 Dynamic Vibration Absorbers 429 8.6.1 Undamped Absorbers 429	11.3 Qualitative Analysis of Nonlinear Systems 553
8.6.2 Damped Vibration Absorbers 434	11.4 Quantitative Methods of Analysis 557
8.6.3 Multi-Degree-of-Freedom Systems 439	11.5 Free Vibrations of One-Degree-
8.7 Vibration Dampers 444 Problems 445	of-Freedom Systems 559 11.6 Forced Vibrations of One-Degree-of-
MATLAB Problems 452	Freedom Systems with Cubic
MAILIBITION	Nonlinearities 564
Chapter 9	11.7 Multi-Degree-of-Freedom Systems 570
VIBRATIONS OF CONTINUOUS	11.7.1 Free Vibrations 571
Systems 455	11.7.2 Forced Vibrations 571
	11.8 Continuous Systems 572 11.9 Chaos 573
9.1 Introduction 455 9.2 General Method 457	Problems 582
9.3 Torsional Oscillations of a Circular	MATLAB Problems 587
Shaft 461	
9.3.1 Problem Formulation 461	Appendix A
9.3.2 Free-Vibration Solutions 465	Unit Impulse Function and Unit
9.4 Transverse Beam Vibrations 473 9.4.1 Problem Formulation 473	STEP FUNCTION 589
9.4.1 Problem Formulation 473 9.4.2 Free Vibrations 476	Appendix B
9.4.3 Forced Vibrations 481	LAPLACE TRANSFORMS 591
9.5 Energy Methods 486	LAPLACE TRANSFORMS 591
Problems 491	Appendix C
MATLAB Problems 499	Linear Algebra 596
Chapter 10	Appendix D
FINITE-ELEMENT METHOD 501	DEFLECTION OF BEAMS SUBJECT TO
10.1 Introduction 501	CONCENTRATED LOADS 606
10.2 Assumed Modes Method 502	
10.3 General Method 507	Appendix E
10.4 The Bar Element 511	Answers to Selected
10.5 Beam Element 514 10.6 Global Matrices 516	PROBLEMS 610
10.7 Examples 520	References 615
Problems 534	Index 617
MATLAB Problems 541	,
Chapter 11	
Nonlinear Vibrations 547	
11.1 Introduction 547	
11.2 Sources of Nonlinearity 548	