

Contents

Preface	ix
1 Introduction	1
1.1 Idealization of Structures	2
1.2 Degrees of Freedom	3
1.2.1 Lumped-Mass Procedure	4
1.2.2 Generalized Displacements	4
1.3 Time-Dependent Excitations	5
1.4 Rigid-Body Dynamic Equilibrium	6
1.5 Deformable-Body Dynamic Equilibrium	9
1.5.1 Direct Equilibrium	10
1.5.2 Principle of Virtual Work	12
1.6 Introduction to Generalized Single Degree of Freedom Analysis	15
1.6.1 Lumped Structural Mass/Weight	16
1.6.2 Lumped Structural Stiffness of Members	20
1.6.3 Lumped Structural Stiffness of Lateral Force Resisting Systems	23
1.7 Flexural and Shear Stresses in Lateral Force Resisting Portal Systems	32
1.7.1 Equivalent Static Force Analysis	33
1.7.2 Element Level Analysis	33
1.8 Problems	36
2 Free Vibration of Single-Degree-of-Freedom Systems	39
2.1 Free Vibration Response of Undamped SDOF Systems	40
2.1.1 Solution to the Undamped SDOF System Equation of Motion	40
2.1.2 Natural Period and Frequency of Vibration	42
2.1.3 Phase Angle and Maximum Amplitude of Vibration Motion	42
2.2 Free Vibration Response of SDOF Systems with Viscous Damping	46
2.2.1 Critically Damped System	48
2.2.2 Overdamped System	49
2.2.3 Underdamped System	50
2.2.4 Equivalent Structural Damping Modeled with Viscous Damping	52
2.2.5 Logarithmic Decrement	54
2.3 Problems	57

3	Forced Vibration Response of SDOF Systems—Harmonic Loading	61
3.1	Vibration Response of Undamped SDOF Systems Subjected to Harmonic Loading	62
3.2	Vibration Response of Damped SDOF Systems Subjected to Harmonic Loading	71
3.3	Vibration Response of SDOF Systems to Support Excitation	81
3.4	Transmissibility and Vibration Isolation	85
3.4.1	Transmissibility of Force from the Structure to the Foundation	87
3.4.2	Transmissibility of Vibration from the Foundation to the Structure	88
3.4.3	Force and Motion Vibration Isolation	91
3.5	Damping Evaluation Using Response to Harmonic Loading	93
3.5.1	Resonant Amplification Method	94
3.5.2	Half-Power Bandwidth Method	95
3.6	Problems	97
4	Vibration Response of SDOF Systems to General Dynamic Loading	101
4.1	Response of a SDOF System to an Impulse	102
4.2	General Forcing Function and Duhamel's Integral	108
4.3	Numerical Evaluation of Duhamel's Integral	114
4.3.1	Euler's Method	115
4.3.2	Trapezoidal Rule	116
4.3.3	Simpson's Rule	116
4.3.4	MATLAB	120
4.4	Response (Shock) Spectra	125
4.5	Approximate Analysis for Short-Duration Excitation Pulses	135
4.6	Response to Ground Motion	139
4.7	Direct Integration Methods	145
4.7.1	Nigam–Jennings Algorithm (Explicit)	146
4.7.2	Central Difference Method (Explicit)	149
4.7.3	Newmark's Beta Method for Linear Systems (Implicit)	151
4.8	Problems	156
5	Vibration of Generalized SDOF Systems with Distributed Mass and Distributed Stiffness	161
5.1	Discrete System Analysis (Shear Buildings)	162
5.1.1	Forced Vibration Response of Generalized SDOF Discrete Systems	162
5.1.2	Analysis Summary of Generalized SDOF Systems Forced Vibration Response	169
5.1.3	Support Excitation Vibration Response of Generalized SDOF Discrete Systems	175
5.1.4	Analysis Summary of Support Excitation Vibration Response of Generalized SDOF Systems	178

5.2	Continuous Systems Analysis	182
5.2.1	Forced Vibration Response of Generalized SDOF Continuous Systems	183
5.2.2	Support Excitation Vibration Response of Generalized SDOF Continuous Systems	188
5.3	Problems	193
6	Vibration of Multi-Degree-of-Freedom Systems	197
6.1	Generalized Eigenvalue Problem	198
6.2	Undamped Equations of Motion for MDOF System	199
6.2.1	Periods and Mode Shapes for a MDOF System	201
6.2.2	Orthogonality of Mode Shapes (Eigenvectors)	208
6.2.3	Modal Superposition Analysis of Free Vibration Response	211
6.3	Free Vibration Response of MDOF Systems with Viscous Damping	221
6.3.1	Rayleigh Damping for MDOF Systems	222
6.4	Problems	227
7	Forced Vibration of MDOF Systems	231
7.1	Forced Vibration Response of Undamped MDOF Systems	232
7.1.1	Displacements, Nodal Forces, Base Shears, and Overturning Moments	234
7.1.2	Combining Maxima Response Values	236
7.1.3	Harmonic Forcing Function Response	238
7.1.4	General Forcing Function Response	242
7.2	Forced Vibration Response of MDOF Systems with Viscous Damping	247
7.2.1	Harmonic Forcing Function Response with Damping ...	248
7.2.2	General Forcing Function Response with Damping	252
7.2.3	Modal Analysis Method Summary	256
7.3	Support Excitation Vibration Response of MDOF Systems	264
7.3.1	Displacements, Nodal Forces, Base Shears, Overturning Moments, and Modal Masses	267
7.3.2	Modal Analysis Method Summary	276
7.4	Problems	283
	Index	289