

# Contents

<b>PREFACE</b>	<b>ix</b>
<b>THE SI SYSTEM OF UNITS</b>	<b>1</b>
<b>1 OSCILLATORY MOTION</b>	<b>5</b>
1.1 Harmonic Motion	6
1.2 Periodic Motion	9
1.3 Vibration Terminology	12
<b>2 FREE VIBRATION</b>	<b>17</b>
2.1 Vibration Model	17
2.2 Equations of Motion: Natural Frequency	18
2.3 Energy Method	22
2.4 Rayleigh Method: Effective Mass	24
2.5 Principle of Virtual Work	26
2.6 Viscously Damped Free Vibration	28
2.7 Logarithmic Decrement	33
2.8 Coulomb Damping	35

<b>3</b>	<b>HARMONICALLY EXCITED VIBRATION</b>	<b>51</b>
3.1	Forced Harmonic Vibration	51
3.2	Rotating Unbalance	56
3.3	Rotor Unbalance	58
3.4	Whirling of Rotating Shafts	61
3.5	Support Motion	66
3.6	Vibration Isolation	68
3.7	Energy Dissipated by Damping	70
3.8	Equivalent Viscous Damping	73
3.9	Structural Damping	75
3.10	Sharpness of Resonance	77
3.11	Vibration-Measuring Instruments	78
<b>4</b>	<b>TRANSIENT VIBRATION</b>	<b>92</b>
4.1	Impulse Excitation	92
4.2	Arbitrary Excitation	94
4.3	Laplace Transform Formulation	97
4.4	Pulse Excitation and Rise Time	100
4.5	Shock Response Spectrum	103
4.6	Shock Isolation	108
4.7	Finite Difference Numerical Computation	108
4.8	Runge–Kutta Method ( <i>Method 2</i> )	117
<b>5</b>	<b>SYSTEMS WITH TWO OR MORE DEGREES OF FREEDOM</b>	<b>130</b>
5.1	The Normal Mode Analysis	131
5.2	Initial Conditions	135
5.3	Coordinate Coupling	138
5.4	Forced Harmonic Vibration	143
5.5	Digital Computation	145

5.6	Vibration Absorber	150	
5.7	Centrifugal Pendulum Vibration Absorber	152	
5.8	Vibration Damper	154	
<b>6</b>	<b>PROPERTIES OF VIBRATING SYSTEMS</b>		<b>171</b>
6.1	Flexibility Influence Coefficients	172	
6.2	Reciprocity Theorem	175	
6.3	Stiffness Influence Coefficients	176	
6.4	Stiffness Matrix of Beam Elements	179	
6.5	Static Condensation for Pinned Joints	183	
6.6	Orthogonality of Eigenvectors	185	
6.7	Modal Matrix $P$	187	
6.8	Decoupling Forced Vibration Equations	189	
6.9	Modal Damping in Forced Vibration	190	
6.10	Normal Mode Summation	192	
6.11	Equal Roots	195	
6.12	Unrestrained (Degenerate) Systems	197	
<b>7</b>	<b>LAGRANGE'S EQUATION</b>		<b>207</b>
7.1	Generalized Coordinates	207	
7.2	Virtual Work	212	
7.3	Lagrange's Equation	215	
7.4	Kinetic Energy, Potential Energy, and Generalized Force in Terms of Generalized Coordinates $q$	221	
7.5	Assumed Mode Summation	223	
<b>8</b>	<b>COMPUTATIONAL METHODS</b>		<b>234</b>
8.1	Root Solving	235	
8.2	Gauss Elimination	236	
8.3	Matrix Iteration	238	
8.4	Convergence of the Iteration Procedure	240	