CONTENTS

1 **INTRODUCTION** **9**

2 **VIBRATION AS DYNAMIC PROCESS** **11**

2.1. Newton's laws of motion 11

2.2. Plane motion of rigid bodies 14

2.3. Rotation of a rigid body about a fixed point 15

2.4. Equations of motion of a rigid body 17

2.5. Second-order ordinary differential equations with constant coefficients 19

2.5.1. Homogeneous equations 19

2.5.2. Nonhomogeneous equations 24

2.5.3. Initial conditions and complete solution 26

Review questions 27

3 **FUNDAMENTALS OF VIBRATION** **29**

3.1. Basic concepts of vibration 29

3.2. Classification of vibration 33

3.3. Parameters of vibration 36

3.4. Vibration analysis procedure 41

Review questions 46

4 **FREE VIBRATION OF UNDAMPED SINGLE DEGREE OF FREEDOM SYSTEMS** **47**

4.1. Simple harmonic oscillation 47

4.2. Free vibration of an undamped torsional system 54

4.3. Energy methods 60

4.4. Stability conditions 64

Review questions 67

5 **FREE VIBRATION OF DAMPED SINGLE DEGREE OF FREEDOM SYSTEMS** **69**

5.1. Free vibration with viscous damping 69

5.2. Torsional system with viscous damping 77

5.3. Free vibration with Coulomb damping 79

5.4. Torsional system with Coulomb damping 85

Review questions 87

6 FORCED VIBRATION OF SINGLE DEGREE OF FREEDOM SYSTEMS 89

6.1. Harmonically excited vibration of an undamped system 89

6.2. Harmonically excited vibration of a damped system 99

6.2.1. Response of a damped system under harmonic force 99

6.2.2. Response of a damped system under rotating unbalance 103

6.2.3. Whirling of rotating shafts 106

6.2.4. Response of a viscously damped system under the harmonic motion of the base 109

6.2.5. Vibration isolation 113

6.2.6. Forced vibration of a system with Coulomb damping 116

6.3. Self-excited and flow-induced vibrations 118

6.4. Response under a nonperiodic force 121

Review questions 128

7 VIBRATION OF MULTIDEGREE OF FREEDOM SYSTEMS 129

7.1. Two degree of freedom systems 129

7.1.1. Equations of motion for forced vibration 129

7.1.2. Free vibration of an undamped system 133

7.1.3. Response of an undamped system under harmonic force 141

7.2. Multidegree of freedom systems 145

7.2.1. Equations of motion 145

7.2.2. Eigenvalue problem 151

7.2.3. Harmonically excited vibration of undamped systems 155

7.2.4. Forced vibration of undamped systems using modal analysis 157

7.2.5. Forced vibration of viscously damped systems 159

7.3. Analogy between mechanical and electric systems 164

Review questions 169

8 VIBRATION OF CONTINUOUS SYSTEMS 171

8.1. Modeling of vibrating systems 171

8.2. Longitudinal vibration of a rod 173

8.3. Torsional vibration of a shaft or rod 183

8.4. Lateral vibration of beams 188

Review questions 199

9 VIBRATION IN SHIPS 201
9.1. Explanatory notes 201
9.1.1. Effects of vibration 201
9.1.2. Environmental factors 203
9.2. Main excitation sources 205
9.2.1. Wave-induced vibration 205
9.2.2. Propeller-induced vibration 212
9.2.3. Vibration of piston engines 214
9.2.4. Shafting vibration 222
9.3. Vibration criteria 227
Review questions 234
10 CONCLUDING REMARKS 235
References 236
Appendix 237
Beaufort Scale 243
Abstract 244