

CONTENTS

| | |
|------------------|---|
| PREFACE. | v |
|------------------|---|

| | |
|---------------------------|---|
| LIST OF SYMBOLS | x |
|---------------------------|---|

CHAPTER I

KINEMATICS OF VIBRATION

| | |
|--|----|
| 1. Definitions | 1 |
| 2. The Vector Method of Representing Vibrations | 3 |
| 3. Beats | 6 |
| 4. A Case of Hydraulic-turbine Penstock Vibration. | 8 |
| 5. Representation by Complex Numbers | 11 |
| 6. Work Done on Harmonic Motions. | 14 |
| 7. Non-harmonic Periodic Motions. | 19 |

CHAPTER II

THE SINGLE DEGREE OF FREEDOM SYSTEM

| | |
|--|----|
| 8. Degrees of Freedom | 34 |
| 9. Derivation of the Differential Equation. | 36 |
| 10. Other Cases. | 38 |
| 11. Free Vibrations without Damping. | 43 |
| 12. Examples. | 47 |
| 13. Free Vibrations with Viscous Damping. | 51 |
| 14. Forced Vibrations without Damping. | 57 |
| 15. Forced Vibrations with Viscous Damping. | 63 |
| 16. Frequency Measuring Instruments. | 72 |
| 17. Seismic Instruments | 75 |
| 18. Electrical Measuring Instruments | 80 |
| 19. Theory of Vibration Isolation. | 89 |
| 20. Application to Single-phase Electrical Machinery | 92 |
| 21. Application to Automobiles; Floating Power | 96 |

CHAPTER III

TWO DEGREES OF FREEDOM

| | |
|--|-----|
| 22. Free Vibrations; Natural Modes. | 103 |
| 23. The Undamped Dynamic Vibration Absorber. | 112 |
| 24. The Damped Vibration Absorber | 119 |

| | |
|--|-----|
| 25. Ship Stabilization by Means of Frahm's Tanks | 133 |
| 26. Gyroscopic Ship Stabilizers | 139 |
| 26a. Activated Ship Stabilizers | 142 |
| 27. Automobile Shock Absorbers | 145 |

CHAPTER IV

MANY DEGREES OF FREEDOM

| | |
|--|-----|
| 28. Free Vibrations without Damping | 155 |
| 29. Forced Vibrations without Damping | 160 |
| 30. Free and Forced Vibration with Damping | 165 |
| 31. Strings and Organ Pipes; Longitudinal and Torsional Vibrations of Uniform Bars | 170 |
| 32. Rayleigh's Method | 178 |
| 33. Bending Vibrations of Uniform Beams | 185 |
| 34. Beams of Variable Cross Section | 194 |
| 35. Normal Functions and Their Applications | 198 |
| 35a. Stodola's Method for Higher Modes | 202 |
| 36. Rings, Membranes, and Plates | 205 |

CHAPTER V

MULTICYLINDER ENGINES

| | |
|---|-----|
| 37. Troubles Peculiar to Reciprocating Engines | 213 |
| 38. Dynamics of the Crank Mechanism | 217 |
| 39. Inertia Balance of Multicylinder Engines | 225 |
| 40. Natural Frequencies of Torsional Vibration | 232 |
| 41. Numerical Calculation of Diesel Ship Drive | 236 |
| 42. Torque Analysis | 248 |
| 43. Work Done by Torque on Crank-shaft Oscillation | 254 |
| 44. Damping of Torsional Vibration | 260 |
| 45. Dampers and Other Means of Mitigating Torsional Vibration | 266 |

CHAPTER VI

ROTATING MACHINERY

| | |
|---|-----|
| 46. Critical Speeds | 285 |
| 46a. Holzer's Method for Flexural Critical Speeds | 290 |
| 47. Balancing of Solid Rotors | 292 |
| 48. Simultaneous Balancing in Two Planes | 300 |
| 49. Balancing of Flexible Rotors; Field Balancing | 305 |
| 50. Secondary Critical Speeds | 309 |
| 50a. Critical Speeds of Helicopter Rotors | 312 |
| 51. Gyroscopic Effects | 317 |

CONTENTS

52. Frame Vibration in Electrical Machines 323
 53. Vibration of Propellers. 328
 54. Vibration of Steam-turbine Wheels and Blades 337

CHAPTER VII

SELF-EXCITED VIBRATIONS

55. General. 346
 56. Mathematical Criterion of Stability 350
 57. Instability Caused by Friction. 354
 58. Internal Hysteresis of Shafts and Oil-film Lubrication in Bearings as Causes of Instability 361
 59. Galloping of Electric Transmission Lines 366
 60. Autorotation; Instability Caused by Finite Speed of Formation of Turbulence. 375
 61. Hunting of Steam-engine Governors 377
 62. Diesel-engine Fuel-injection Valves. 382
 63. Axial Oscillation of Turbine Caused by Steam Leakage. . . 386
 64. Airplane-wing Flutter. 392
 65. Automobile Shimmy. 399

CHAPTER VIII

SYSTEMS WITH VARIABLE OR NON-LINEAR CHARACTERISTICS

66. The Principle of Superposition. 406
 67. Examples of Systems with Variable Elasticity. 408
 68. Solution of the Equation 415
 69. Interpretation of the Result. 420
 70. Examples of Non-linear Systems. 424
 71. Free Vibrations with Non-linear Elasticity or Damping. . . 427
 72. Forced Vibrations with Non-linear Springs 431
 73. Forced Vibrations with Non-linear Damping 435
 74. Relaxation Oscillations. 439
 75. Subharmonic Resonance 448

APPENDICES

I. THE GYROSCOPE 453
 II. A COLLECTION OF FORMULAS 457
 BIBLIOGRAPHY 461
 ANSWERS TO PROBLEMS 466
 INDEX. 475