

# Contents

---

|                                                           |           |
|-----------------------------------------------------------|-----------|
| <b>Preface</b>                                            | <b>ix</b> |
| <b>CHAPTER 1 ■ Simple Harmonic Oscillation</b>            | <b>1</b>  |
| 1.1 Introduction . . . . .                                | 1         |
| 1.2 Mass on Spring . . . . .                              | 1         |
| 1.3 Simple Harmonic Oscillator Equation . . . . .         | 5         |
| 1.4 LC Circuit . . . . .                                  | 8         |
| 1.5 Simple Pendulum . . . . .                             | 11        |
| 1.6 Compound Pendulum . . . . .                           | 12        |
| Exercises . . . . .                                       | 14        |
| <b>CHAPTER 2 ■ Damped and Driven Harmonic Oscillation</b> | <b>19</b> |
| 2.1 Introduction . . . . .                                | 19        |
| 2.2 Damped Harmonic Oscillation . . . . .                 | 19        |
| 2.3 Quality Factor . . . . .                              | 22        |
| 2.4 LCR Circuit . . . . .                                 | 23        |
| 2.5 Driven Damped Harmonic Oscillation . . . . .          | 25        |
| 2.6 Driven LCR Circuit . . . . .                          | 29        |
| 2.7 Transient Oscillator Response . . . . .               | 30        |
| Exercises . . . . .                                       | 33        |
| <b>CHAPTER 3 ■ Coupled Oscillations</b>                   | <b>37</b> |
| 3.1 Introduction . . . . .                                | 37        |
| 3.2 Two Spring-Coupled Masses . . . . .                   | 37        |
| 3.3 Two Coupled LC Circuits . . . . .                     | 41        |
| 3.4 Three Spring-Coupled Masses . . . . .                 | 44        |
| Exercises . . . . .                                       | 46        |
| <b>CHAPTER 4 ■ Transverse Standing Waves</b>              | <b>49</b> |
| 4.1 Introduction . . . . .                                | 49        |
| 4.2 Normal Modes of Beaded String . . . . .               | 49        |
| 4.3 Normal Modes of Uniform String . . . . .              | 56        |
| 4.4 General Time Evolution of Uniform String . . . . .    | 58        |
| Exercises . . . . .                                       | 66        |
| <b>CHAPTER 5 ■ Longitudinal Standing Waves</b>            | <b>69</b> |
| 5.1 Introduction . . . . .                                | 69        |
| 5.2 Spring-Coupled Masses . . . . .                       | 69        |
| 5.3 Longitudinal Waves on Thin Elastic Rod . . . . .      | 73        |

|                                            |                                                            |            |
|--------------------------------------------|------------------------------------------------------------|------------|
| 5.4                                        | Sound Waves in Ideal Gas . . . . .                         | 77         |
| 5.5                                        | Fourier Analysis . . . . .                                 | 79         |
|                                            | <i>Exercises</i> . . . . .                                 | 84         |
| <b>CHAPTER 6 ■ Traveling Waves</b>         |                                                            | <b>87</b>  |
| 6.1                                        | Introduction . . . . .                                     | 87         |
| 6.2                                        | Standing Waves in Finite Continuous Medium . . . . .       | 87         |
| 6.3                                        | Traveling Waves in Infinite Continuous Medium . . . . .    | 88         |
| 6.4                                        | Wave Interference . . . . .                                | 90         |
| 6.5                                        | Energy Conservation . . . . .                              | 91         |
| 6.6                                        | Transmission Lines . . . . .                               | 94         |
| 6.7                                        | Normal Reflection and Transmission at Interfaces . . . . . | 98         |
| 6.8                                        | Electromagnetic Waves . . . . .                            | 103        |
| 6.9                                        | Doppler Effect . . . . .                                   | 107        |
| 6.10                                       | Wave Propagation in Inhomogeneous Media . . . . .          | 109        |
|                                            | <i>Exercises</i> . . . . .                                 | 110        |
| <b>CHAPTER 7 ■ Multi-Dimensional Waves</b> |                                                            | <b>117</b> |
| 7.1                                        | Introduction . . . . .                                     | 117        |
| 7.2                                        | Plane Waves . . . . .                                      | 117        |
| 7.3                                        | Three-Dimensional Wave Equation . . . . .                  | 118        |
| 7.4                                        | Cylindrical Waves . . . . .                                | 119        |
| 7.5                                        | Spherical Waves . . . . .                                  | 120        |
| 7.6                                        | Oscillation of an Elastic Sheet . . . . .                  | 120        |
| 7.7                                        | Polarization of Electromagnetic Waves . . . . .            | 123        |
| 7.8                                        | Laws of Geometric Optics . . . . .                         | 125        |
| 7.9                                        | Fresnel Relations . . . . .                                | 127        |
| 7.10                                       | Total Internal Reflection . . . . .                        | 132        |
| 7.11                                       | Birefringence . . . . .                                    | 137        |
| 7.12                                       | Sound Waves in Fluids . . . . .                            | 143        |
|                                            | <i>Exercises</i> . . . . .                                 | 146        |
| <b>CHAPTER 8 ■ Wave Pulses</b>             |                                                            | <b>149</b> |
| 8.1                                        | Introduction . . . . .                                     | 149        |
| 8.2                                        | Fourier Transforms . . . . .                               | 149        |
| 8.3                                        | Dirac Delta Function . . . . .                             | 152        |
| 8.4                                        | General Solution of 1D Wave Equation . . . . .             | 154        |
| 8.5                                        | Bandwidth . . . . .                                        | 157        |
| 8.6                                        | Bandwidth Theorem . . . . .                                | 160        |
|                                            | <i>Exercises</i> . . . . .                                 | 161        |
| <b>CHAPTER 9 ■ Dispersive Waves</b>        |                                                            | <b>165</b> |
| 9.1                                        | Introduction . . . . .                                     | 165        |
| 9.2                                        | Pulse Propagation . . . . .                                | 165        |
| 9.3                                        | Electromagnetic Waves in Unmagnetized Plasmas . . . . .    | 167        |
| 9.4                                        | Faraday Rotation . . . . .                                 | 173        |
| 9.5                                        | Electromagnetic Waves in Magnetized Plasmas . . . . .      | 176        |

|                                    |                                                        |            |
|------------------------------------|--------------------------------------------------------|------------|
| 9.6                                | Low-Frequency EM Waves in Magnetized Plasmas . . . . . | 181        |
| 9.7                                | Parallel EM Waves in Magnetized Plasmas . . . . .      | 182        |
| 9.8                                | Perpendicular EM Waves in Magnetized Plasmas . . . . . | 185        |
| 9.9                                | Electromagnetic Waves in Conductors . . . . .          | 187        |
| 9.10                               | Waveguides . . . . .                                   | 190        |
| 9.11                               | Pulse Propagation in Two Dimensions . . . . .          | 191        |
| 9.12                               | Gravity Waves . . . . .                                | 194        |
| 9.13                               | Wave Drag on Ships . . . . .                           | 199        |
| 9.14                               | Ship Wakes . . . . .                                   | 201        |
| 9.15                               | Capillary Waves . . . . .                              | 205        |
|                                    | <i>Exercises</i> . . . . .                             | 207        |
| <b>CHAPTER 10 ■ Wave Optics</b>    |                                                        | <b>213</b> |
| 10.1                               | Introduction . . . . .                                 | 213        |
| 10.2                               | Two-Slit Interference . . . . .                        | 213        |
| 10.3                               | Coherence . . . . .                                    | 219        |
| 10.4                               | Multi-Slit Interference . . . . .                      | 224        |
| 10.5                               | Thin-Film Interference . . . . .                       | 227        |
| 10.6                               | One-Dimensional Fourier Optics . . . . .               | 228        |
| 10.7                               | Single-Slit Diffraction . . . . .                      | 229        |
| 10.8                               | Multi-Slit Diffraction . . . . .                       | 231        |
| 10.9                               | Two-Dimensional Fourier Optics . . . . .               | 233        |
| 10.10                              | Huygens–Fresnel Principle . . . . .                    | 237        |
| 10.11                              | Babinet’s Principle . . . . .                          | 241        |
| 10.12                              | Diffraction from Rectangular Aperture . . . . .        | 241        |
| 10.13                              | Diffraction from Straight Edge . . . . .               | 243        |
| 10.14                              | Diffraction from Rectangular Slit . . . . .            | 244        |
| 10.15                              | Diffraction from Straight Wire . . . . .               | 244        |
| 10.16                              | Diffraction from Circular Aperture . . . . .           | 247        |
| 10.17                              | Diffraction from Circular Disk . . . . .               | 249        |
|                                    | <i>Exercises</i> . . . . .                             | 250        |
| <b>CHAPTER 11 ■ Wave Mechanics</b> |                                                        | <b>257</b> |
| 11.1                               | Introduction . . . . .                                 | 257        |
| 11.2                               | Photoelectric Effect . . . . .                         | 258        |
| 11.3                               | Electron Diffraction . . . . .                         | 259        |
| 11.4                               | Representation of Waves via Complex Numbers . . . . .  | 259        |
| 11.5                               | Schrödinger’s Equation . . . . .                       | 261        |
| 11.6                               | Probability Interpretation of Wavefunction . . . . .   | 262        |
| 11.7                               | Wave Packets . . . . .                                 | 264        |
| 11.8                               | Heisenberg’s Uncertainty Principle . . . . .           | 267        |
| 11.9                               | Wavefunction Collapse . . . . .                        | 268        |
| 11.10                              | Stationary States . . . . .                            | 269        |
| 11.11                              | Particle in Finite Square Potential Well . . . . .     | 271        |
| 11.12                              | Square Potential Barrier . . . . .                     | 274        |
| 11.13                              | WKB Approximation . . . . .                            | 279        |
| 11.14                              | Cold Emission . . . . .                                | 281        |

|                                                  |            |
|--------------------------------------------------|------------|
| 11.15 Alpha Decay . . . . .                      | 282        |
| 11.16 Three-Dimensional Wave Mechanics . . . . . | 284        |
| 11.17 Particle in Box . . . . .                  | 285        |
| 11.18 Degenerate Electron Gas . . . . .          | 287        |
| 11.19 White-Dwarf Star . . . . .                 | 289        |
| Exercises . . . . .                              | 290        |
| <b>Bibliography</b> . . . . .                    | <b>293</b> |
| <b>Index</b> . . . . .                           | <b>295</b> |