Contents

About the Author *ix*
Editors' Preface to the Manchester Physics Series *x*
Preface to First Edition *xi*
Preface to Second Edition *xiii*
About the Companion Website *xiv*

1 Simple Harmonic Motion *1*
1.1 Physical Characteristics of Simple Harmonic Oscillators *1*
1.2 A Mass on a Spring *2*
1.2.1 A Mass on a Horizontal Spring *2*
1.2.2 A Mass on a Vertical Spring *4*
1.2.3 Displacement, Velocity and Acceleration in SHM *5*
1.2.4 General Solutions for SHM and the Phase Angle ϕ *7*
1.2.5 The Energy of a Simple Harmonic Oscillator *9*
1.2.6 The Physics of Small Vibrations *11*
1.3 The Pendulum *16*
1.3.1 The Simple Pendulum *16*
1.3.2 The Energy of a Simple Pendulum *18*
1.3.3 The Physical Pendulum *21*
1.3.4 Numerical Solution of SHM *23*
1.4 Oscillations in Electrical Circuits: Similarities in Physics *26*
1.4.1 The *LC* Circuit *26*
1.4.2 Similarities in Physics *27*
Problems 1 *29*

2 The Damped Harmonic Oscillator *35*
2.1 Physical Characteristics of Damped Harmonic Oscillators *35*
2.2 The Equation of Motion for a Damped Harmonic Oscillator *36*
2.2.1 Light Damping *37*
2.2.2 Heavy Damping *40*
2.2.3 Critical Damping *40*
2.3 Rate of Energy Loss in a Damped Harmonic Oscillator *43*
2.3.1 The Quality Factor *Q* of a Damped Harmonic Oscillator *44*
2.4 Damped Electrical Oscillations *47*
Problems 2 *49*

3 Forced Oscillations *53*
3.1 Physical Characteristics of Forced Harmonic Motion *54*
3.2 The Equation of Motion of a Forced Harmonic Oscillator *54*
3.2.1 Undamped Forced Oscillations *54*
3.2.2 Forced Oscillations with Damping *57*
3.3 Power Absorbed During Forced Oscillations *63*
3.4 Resonance in Electrical Circuits *68*
3.5 Transient Phenomena *70*
3.6 The Complex Representation of Oscillatory Motion *72*
3.6.1 Complex Numbers *72*
3.6.2 The Use of Complex Numbers to Represent Physical Quantities *75*
3.6.3 Use of the Complex Representation for Forced Oscillations with Damping *76*
Problems 3 *78*

4 Coupled Oscillators *85*
4.1 Physical Characteristics of Coupled Oscillators *85*
4.2 Normal Modes of Oscillation *86*
4.3 Superposition of Normal Modes *89*
4.4 Oscillating Masses Coupled by Springs *93*
4.5 Forced Oscillations of Coupled Oscillators *101*
4.6 Transverse Oscillations *104*
Problems 4 *108*

5 Travelling Waves *115*
5.1 Physical Characteristics of Waves *116*
5.2 Travelling Waves *116*
5.2.1 Travelling Sinusoidal Waves *119*
5.3 The Wave Equation *122*
5.4 The Equation of a Vibrating String *124*
5.5 The Energy in a Wave *126*
5.6 The Transport of Energy by a Wave *129*
5.7 Waves at Discontinuities *130*
5.8 Waves in Two and Three Dimensions *134*
5.8.1 Waves of Circular or Spherical Symmetry *138*
Problems 5 *141*

6 Standing Waves *147*
6.1 Standing Waves on a String *147*
6.2 Standing Waves as the Superposition of Two Travelling Waves *153*
6.3 The Energy in a Standing Wave *155*
6.4 Standing Waves as Normal Modes of a Vibrating String *157*
6.4.1 The Superposition Principle *157*
6.4.2 The Superposition of Normal Modes *158*
6.4.3 The Amplitudes of Normal Modes and Fourier Analysis *161*
6.4.4 The Energy of Vibration of a String *163*
Problems 6 *165*

7 Interference and Diffraction of Waves *169*
7.1 Interference and Huygens' Principle *169*
7.1.1 Young's Double-Slit Experiment *172*
7.1.2 Michelson Spectral Interferometer *178*
7.2 Diffraction *180*
7.2.1 Diffraction at a Single Slit *181*
7.2.2 Circular Apertures and Angular Resolving Power *185*
7.2.3 Double Slits of Finite Width *187*
Problems 7 *188*

8 The Dispersion of Waves *193*
8.1 The Superposition of Waves in Non-Dispersive Media *193*
8.1.1 Beats *194*
8.1.2 Amplitude Modulation of a Radio Wave *196*
8.2 The Dispersion of Waves *197*
8.2.1 Phase and Group Velocities *197*
8.3 The Dispersion Relation *201*
8.4 Wave Packets *204*
8.4.1 Formation of a Wave Packet *205*
Problems 8 *209*

Appendix: Solutions to Problems *215*
Index *237*