

Table of Contents

Preface	xi
Chapter 1. Free Oscillations	1
1.1. Oscillations and waves, period and frequency	1
1.2. Simple harmonic vibrations: differential equation and linearity	2
1.3. Complex representation and phasor representation	5
1.4. Point mass subject to a force $-Kx$	9
1.5. Angular oscillations	12
1.6. Damped oscillations	15
1.7. Dissipation of the energy of a damped oscillator	19
1.8. Oscillating LCR circuits	20
1.9. Small oscillations of a system with one degree of freedom	22
1.10. Nonlinear oscillators	25
1.11. Systems with two degrees of freedom	25
1.12. Generalization to systems with n degrees of freedom	29
1.13. Normal variables for systems with n degrees of freedom*	32
1.14. Summary	35
1.15. Problem solving suggestions	38
1.16. Conceptual questions	39
1.17. Problems	40
Chapter 2. Superposition of Harmonic Oscillations, Fourier Analysis	51
2.1. Superposition of two scalar and isochronous simple harmonic oscillations	51
2.2. Superposition of two perpendicular and isochronous vector oscillations, polarization	53
2.3. Superposition of two perpendicular and non-isochronous oscillations	57

Mechanical and Electromagnetic Vibrations and Waves

2.4. Superposition of scalar non-synchronous harmonic oscillations, beats	58
2.5. Fourier analysis of a periodic function	60
2.6. Fourier analysis of a non-periodic function	65
2.7. Fourier analysis of a signal, uncertainty relation	67
2.8. Dirac delta-function	69
2.9. Summary	71
2.10. Problem solving suggestions	74
2.11. Conceptual questions	75
2.12. Problems.	76
Chapter 3. Forced Oscillations	83
3.1. Transient regime and steady regime	83
3.2. Case of a simple harmonic excitation force	85
3.3. Resonance.	87
3.4. Impedance and energy of a forced oscillator in the steady regime.	88
3.5. Complex impedance.	92
3.6. Sustained electromagnetic oscillations.	94
3.7. Excitation from a state of equilibrium*	96
3.8. Response to an arbitrary force, nonlinear systems*	97
3.9. Excitation of a system of coupled oscillators*	99
3.10. Generalization of the concepts of external force and impedance*	103
3.11. Some applications	104
3.12. Summary	105
3.13. Problem solving suggestions	106
3.14. Conceptual questions	107
3.15. Problems.	108
Chapter 4. Propagation in Infinite Media	115
4.1. Propagation of one-dimensional waves	115
4.2. Propagation of two- and three-dimensional waves.	117
4.3. Propagation of a vector wave	121
4.4. Polarization of a transverse vector wave.	123
4.5. Monochromatic wave, wave vector and wavelength.	125
4.6. Dispersion.	127
4.7. Group velocity	129
4.8. Fourier analysis for waves*	130
4.9. Modulation*	133
4.10. Energy of waves	135
4.11. Other unattenuated wave equations, conserved quantities*	137

Table of Contents

4.12. Impedance of a medium*	139
4.13. Attenuated waves	140
4.14. Sources and observers in motion, the Doppler effect and shock waves	143
4.15. Summary	148
4.16. Problem solving suggestions	150
4.17. Conceptual questions	152
4.18. Problems.	153
Chapter 5. Mechanical Waves	159
5.1. Transverse waves on a taut string	159
5.2. Strain and stress in elastic solids	162
5.3. Elastic waves in massive springs and rods	166
5.4. Propagation of sound in a pipe	168
5.5. Transverse waves on elastic membranes.	172
5.6. Mechanical waves in three dimensions	174
5.7. Energy of mechanical waves.	176
5.8. Progressive waves, impedance and intensity	179
5.9. Elements of physiological acoustics	183
5.10. Infrasounds and ultrasounds	185
5.11. Surface waves*	186
5.12. Summary	191
5.13. Problem solving suggestions	194
5.14. Conceptual questions	194
5.15. Problems.	195
Chapter 6. Electromagnetic Waves	201
6.1. Principal results of the electromagnetic theory	201
6.2. The propagation equations of the fields in vacuum and infinite dielectrics.	204
6.3. Electromagnetic simple harmonic plane waves.	205
6.4. Energy density and the Poynting vector	206
6.5. Polarization of electromagnetic waves.	207
6.6. Momentum density and angular momentum density, radiation pressure*	209
6.7. Electromagnetic waves in plasmas*	212
6.8. Electromagnetic waves in Ohmic conductors*	214
6.9. Quantization of electromagnetic radiation.	218
6.10. Electromagnetic spectrum	219
6.11. Emission of electromagnetic radiations	221
6.12. Spontaneous emission and stimulated emission.	223
6.13. Summary	226

Mechanical and Electromagnetic Vibrations and Waves

6.14. Problem solving suggestions	229
6.15. Conceptual questions	229
6.16. Problems.	231
Chapter 7. Reflection and Refraction of Waves	237
7.1. Reflection of an elastic wave on two joined strings	237
7.2. Reflection and transmission of a one-dimensional acoustic wave.	240
7.3. General laws of reflection and transmission of three-dimensional waves	243
7.4. Reflection and refraction of a three-dimensional acoustic wave	246
7.5. Reflection and refraction of an electromagnetic wave at the interface of dielectrics	248
7.5.1. Case of linear polarization in the plane of incidence	249
7.5.2. Case of linear polarization perpendicular to the plane of incidence.	250
7.5.3. Conservation of energy	252
7.5.4. Brewster's law	253
7.6. Case of attenuated waves in the second medium*	255
7.7. Summary	258
7.8. Problem solving suggestions.	260
7.9. Conceptual questions	261
7.10. Problems.	262
Chapter 8. Interference and Diffraction	269
8.1. Order and fringes of interference of two waves	269
8.2. Intensity and contrast	271
8.3. Interference of light waves, Young's experiment	273
8.4. Multiwave interference, conditions for interference	277
8.5. Holography	281
8.6. Thin film interference.	282
8.7. The Huygens-Fresnel principle and diffraction by an aperture.	285
8.8. Diffraction grating.	290
8.9. Diffraction of X-rays	295
8.10. Summary	297
8.11. Problem solving suggestions	299
8.12. Conceptual questions	300
8.13. Problems.	301
Chapter 9. Standing Waves and Guided Waves	307
9.1. One-dimensional standing waves	308

9.2. Standing waves on a membrane and in a rectangular cavity	313
9.3. Fourier analysis of standing waves*	316
9.4. Resonance and standing waves	319
9.5. Sound wave guided by two parallel plates.	320
9.6. Guided sound waves in a rectangular pipe.	322
9.7. Transmission lines.	324
9.8. Electromagnetic waveguides*	326
9.9. Waveguides formed by two plane and parallel plates*	328
9.10. Guided electromagnetic waves in a hollow conductor*	331
9.11. Applications of waveguides	335
9.12. Summary	337
9.13. Problem solving suggestions	340
9.14. Conceptual questions	341
9.15. Problems.	342
Answers to the Problems	349
APPENDICES	371
Appendix A. Mathematical Review	373
A.1. Expansion formulas.	373
A.2. Logarithmic, exponential and hyperbolic functions	374
A.3. Trigonometric functions	374
A.4. Integrals	375
A.5. Complex numbers.	378
A.6. Vector analysis in Cartesian coordinates	380
A.7. Vector analysis in curvilinear coordinates	382
Appendix B. Units in Physics	387
B.1. Multiples and submultiples of units	387
B.2. Fundamental and derived SI units	387
B.3. Mechanical units	388
B.4. Electromagnetic units.	389
Appendix C. Some Physical Constants	391
C.1. Mechanical and thermodynamic constants	391
C.2. Electromagnetic and atomic constants.	392
Further Reading	393
Index	395