

# Contents

<i>Preface</i>	<i>page</i> ix
<i>Acknowledgements</i>	x
<i>Symbols</i>	xi
<b>1 The essence of wave motion</b>	<b>1</b>
1.1 Introduction	1
1.2 A local view of wave propagation	2
1.3 Cause and effect	4
1.4 Examples of wave disturbance	9
Exercises	10
<b>2 Wave equations and their solution</b>	<b>12</b>
2.1 Wave equations	12
2.2 Waves on long strings	17
Exercises	22
<b>3 Further wave equations</b>	<b>23</b>
3.1 Waves along a coaxial cable	23
3.2 Electromagnetic waves	28
3.3 Ocean waves	30
3.4 Capillary waves	37
3.5 Gravity waves in compressible fluids	40
3.6 Waves and weather	44
Exercises	46
<b>4 Sinusoidal waveforms</b>	<b>47</b>
4.1 Sinusoidal solutions	47
4.2 Energy of a wave motion	50
4.3 The tsunami	53
4.4 Normal modes, standing waves and orthogonality	57
Exercises	62
<b>5 Complex wavefunctions</b>	<b>63</b>
5.1 Complex harmonic waves	63
5.2 Dispersion in dissipative systems	65

5.3	Phasors and geometric series	67
	Exercises	69
<b>6</b>	<b>Huygens wave propagation</b>	<b>71</b>
6.1	Huygens' model of wave propagation	71
6.2	Propagation in free space	71
6.3	Reflection at an interface	77
6.4	Refraction at an interface	78
6.5	Fermat's principle of least time	81
	Exercises	82
<b>7</b>	<b>Geometrical optics</b>	<b>85</b>
7.1	Ray optics	85
7.2	Refraction at a spherical surface	86
7.3	The thin lens	90
7.4	Fermat's principle in imaging	92
	Exercises	93
<b>8</b>	<b>Interference</b>	<b>96</b>
8.1	Wave propagation around obstructions	96
8.2	Young's double-slit experiment	97
8.3	Wavefront dividers	100
8.4	The Michelson interferometer	101
	Exercises	104
<b>9</b>	<b>Fraunhofer diffraction</b>	<b>106</b>
9.1	More wave propagation around obstructions	106
9.2	Diffraction by a single slit	107
9.3	Babinet's principle	111
9.4	The diffraction grating	112
9.5	Wavefront reconstruction and holography	119
9.6	Definition of Fraunhofer diffraction	121
9.7	The resolution of an imaging system	123
	Exercises	123
<b>10</b>	<b>Longitudinal waves</b>	<b>125</b>
10.1	Further examples of wave propagation	125
10.2	Sound waves in an elastic medium	125
10.3	Thermal waves	129
	Exercises	132
<b>11</b>	<b>Continuity conditions</b>	<b>134</b>
11.1	Wave propagation in changing media	134
11.2	The frayed guitar string	134

11.3	General continuity conditions and characteristic impedance	140
11.4	Reflection and transmission by multiple interfaces	143
11.5	Total internal reflection	146
11.6	Frustrated total internal reflection	152
11.7	Applications of internal reflection and evanescent fields	154
11.8	Evanescent-wave confusions and conundrums	155
	Exercises	156
<b>12</b>	<b>Boundary conditions</b>	<b>158</b>
12.1	The imposition of external constraints	158
12.2	The guitar and other stringed musical instruments	159
12.3	Organ pipes and wind instruments	161
12.4	Boundary conditions in other systems	165
12.5	Driven boundaries	167
12.6	Cyclic boundary conditions	167
	Exercises	169
<b>13</b>	<b>Linearity and superpositions</b>	<b>171</b>
13.1	Wave motions in linear systems	171
13.2	Linearity and the superposition principle	172
13.3	Wavepackets	173
13.4	Dispersion and the group velocity	176
	Exercises	179
<b>14</b>	<b>Fourier series and transforms</b>	<b>180</b>
14.1	Fourier synthesis and analysis	180
14.2	Fourier series and the analysis of a periodic function	182
14.3	Alternative forms of the Fourier transform	186
14.4	Mathematical justification of Fourier's principle	188
14.5	The spectrum	192
14.6	Orthogonality, power calculations and spectral intensities	193
14.7	Fourier analysis of dispersive propagation	195
14.8	The convolution of waveforms	197
14.9	Fourier analysis of Fraunhofer diffraction	201
14.10	Fourier-transform spectroscopy	203
	Exercises	204
<b>15</b>	<b>Waves in three dimensions</b>	<b>207</b>
15.1	Waves in multiple dimensions	207
15.2	Wave equations in two and three dimensions	207
15.3	Plane waves and the wavevector	209
15.4	Fourier transforms in two and three dimensions	211
15.5	Diffraction in three dimensions	212

15.6	Wave radiation in three dimensions	216
15.7	Polarization	219
<b>16</b>	<b>Operators for wave motions</b>	<b>225</b>
16.1	The mathematical operator	225
16.2	Operators for frequency and wavenumber	226
16.3	The expectation value: the mean value of an observable	227
16.4	The uncertainty: the standard deviation of an observable	229
16.5	Operator analysis of a Gaussian wavepacket	230
16.6	Complex electrical impedances	232
	Exercises	233
<b>17</b>	<b>Uncertainty and quantum mechanics</b>	<b>235</b>
17.1	The bandwidth theorem	235
17.2	Wave–particle duality	237
17.3	The quantum-mechanical wavefunction	238
17.4	Measurement of the quantum wavefunction	241
	Exercises	245
<b>18</b>	<b>Waves from moving sources</b>	<b>247</b>
18.1	Waves from slowly moving sources	247
18.2	Waves from quickly moving sources	252
18.3	The wake of a ship under way	256
	Exercises	261
<b>19</b>	<b>Radiation from moving charges</b>	<b>263</b>
19.1	Solution of the electromagnetic wave equation	264
19.2	Retarded electromagnetic potentials	268
19.3	Retarded electromagnetic fields	275
19.4	Radiation from moving charges	279
	Exercises	281
<b>Appendix: Vector mathematics</b>		<b>283</b>
A.1	Cartesian coordinates	283
A.2	Spherical polar coordinates	284
	<i>References</i>	286
	<i>Index</i>	291