

Contents

<i>Preface</i>	<i>page</i>	xiii
<i>Acknowledgements</i>		xv
1 Introduction	1	
1.1 Key concepts	1	
1.2 This book and its reader	1	
1.3 Physical aspects and scales	3	
1.4 The structure of the book	7	
2 Observation techniques	10	
2.1 Key concepts	10	
2.2 Introduction	10	
2.3 <i>In situ</i> techniques	12	
2.3.1 Wave buoys	13	
2.3.2 Wave poles	15	
2.3.3 Other <i>in situ</i> techniques	17	
2.4 Remote-sensing techniques	18	
2.4.1 Imaging techniques	19	
Stereo-photography	19	
Imaging and non-imaging radar	20	
2.4.2 Altimetry	21	
Laser altimetry	21	
Acoustic altimetry	22	
Radar altimetry	22	
3 Description of ocean waves	24	
3.1 Key concepts	24	
3.2 Introduction	24	
3.3 Wave height and period	25	
3.3.1 Waves	25	
3.3.2 Wave height	27	
3.3.3 Wave period	29	

	<i>Contents</i>
3.4 Visual observations and instrumental measurements	29
3.5 The wave spectrum	31
3.5.1 Introduction	31
3.5.2 The random-phase/amplitude model	33
3.5.3 The variance density spectrum	36
3.5.4 Interpretation of the variance density spectrum	38
3.5.5 Alternative definitions	41
The spectral domain	41
Formal definition	42
3.5.6 The frequency–direction spectrum	43
3.5.7 The spectrum at sea	47
3.5.8 Wave-number spectra	48
The one-dimensional wave-number spectrum	49
The two-dimensional wave-number spectrum	49
The three-dimensional frequency–wave-number spectrum	50
3.5.9 Spectrum acquisition	51
3.6 Transfer functions and response spectra	52
 4 Statistics	56
4.1 Key concepts	56
4.2 Short-term statistics	56
4.2.1 Instantaneous surface elevation	57
4.2.2 Wave height and period	60
Wave period	60
Crest height	62
Wave height	68
4.2.3 Wave groups	75
4.2.4 Extreme values	77
Extreme elevations	78
Extreme wave heights	82
4.3 Long-term statistics (wave climate)	85
4.3.1 The initial-distribution approach	87
4.3.2 The peak-over-threshold approach	95
4.3.3 The annual-maximum approach	98
4.3.4 Individual wave height	101
4.3.5 Wave atlases	105
 5 Linear wave theory (oceanic waters)	106
5.1 Key concepts	106
5.2 Introduction	107

<i>Contents</i>	ix
5.3 Basic equations and boundary conditions	107
5.3.1 Idealisations of the water and its motions	108
5.3.2 Balance equations	109
Mass balance and continuity equations	112
Momentum balance	112
5.3.3 Boundary conditions	114
5.3.4 The velocity potential function	115
5.4 Propagating harmonic wave	118
5.4.1 Introduction	118
5.4.2 Kinematics	119
Particle velocity	120
Particle path	121
5.4.3 Dynamics	123
The dispersion relationship	123
Phase velocity and group velocity	125
Wave-induced pressure	128
5.4.4 Capillary waves	129
5.5 Wave energy (transport)	131
5.5.1 Wave energy	131
5.5.2 Energy transport	132
5.6 Nonlinear, permanent waves	137
5.6.1 Introduction	137
5.6.2 Stokes' theory and Dean's stream-function theory	139
5.6.3 Cnoidal and solitary waves	142
 6 Waves in oceanic waters	145
6.1 Key concepts	145
6.2 Introduction	146
6.3 Wave modelling for idealised cases (oceanic waters)	147
6.3.1 Idealised wind	148
6.3.2 The significant wave	150
6.3.3 The one-dimensional wave spectrum	155
6.3.4 The two-dimensional wave spectrum	162
6.4 Wave modelling for arbitrary cases (oceanic waters)	167
6.4.1 The energy balance equation	169
6.4.2 Wave propagation and swell	174
6.4.3 Generation by wind	177
6.4.4 Nonlinear wave–wave interactions (quadruplet)	183
6.4.5 Dissipation (white-capping)	188
6.4.6 Energy flow in the spectrum	192
6.4.7 First-, second- and third-generation wave models	194

x	<i>Contents</i>
7	Linear wave theory (coastal waters) 197
7.1	Key concepts 197
7.2	Introduction 197
7.3	Propagation 199
7.3.1	Shoaling 199
7.3.2	Refraction 202
7.3.3	Diffraction 210
7.3.4	Refraction and diffraction 217
7.3.5	Tides and currents 218
7.3.6	Reflections 221
7.4	Wave-induced set-up and currents 225
7.4.1	Introduction 225
7.4.2	Wave momentum and radiation stress 225
7.4.3	Wave-induced set-up, set-down and currents 234
7.5	Nonlinear, evolving waves 239
7.5.1	Introduction 239
7.5.2	The Boussinesq model 240
7.6	Breaking waves 242
8	Waves in coastal waters 244
8.1	Key concepts 244
8.2	Introduction 245
8.3	Wave modelling for idealised cases (coastal waters) 246
8.3.1	The significant wave 247
8.3.2	The one-dimensional wave spectrum 250
8.3.3	The two-dimensional wave spectrum 256
8.4	Wave modelling for arbitrary cases (coastal waters) 256
8.4.1	The energy/action balance equation 257
8.4.2	Wave propagation 263
8.4.3	Generation by wind 268
8.4.4	Nonlinear wave–wave interactions 269
Quadruplet wave–wave interactions	269
Triad wave–wave interactions	270
8.4.5	Dissipation 276
White-capping	276
Bottom friction	276
Depth-induced (surf-)breaking	281
8.4.6	Energy flow in the spectrum 284

<i>Contents</i>	xi
9 The SWAN wave model	286
9.1 Key concepts	286
9.2 Introduction	286
9.3 Action balance	288
9.3.1 The action balance equation	288
9.3.2 Generation by wind	289
9.3.3 Nonlinear wave–wave interactions	292
Quadruplet wave–wave interactions	292
Triad wave–wave interactions	293
9.3.4 Dissipation	294
White-capping	294
Bottom friction	295
Depth-induced (surf-)breaking	296
Reflection, transmission and absorption	296
9.4 Wave-induced set-up	296
9.5 Numerical techniques	298
9.5.1 Introduction	298
9.5.2 Propagation	299
Numerical schemes	301
Solvers, grids and boundaries	305
9.5.3 Generation, wave–wave interactions and dissipation	306
Positive source terms	307
Negative source terms	307
Numerical stability	308
9.5.4 Wave-induced set-up	309
<i>Appendix A Random variables</i>	310
<i>Appendix B Linear wave theory</i>	318
<i>Appendix C Spectral analysis</i>	324
<i>Appendix D Tides and currents</i>	335
<i>Appendix E Shallow-water equations</i>	342
<i>References</i>	347
<i>Index</i>	379