

Contents

1	INTRODUCTION	1
1.1	Historical background	2
1.1.1	Mostly isotropic media	2
1.1.2	Mostly anisotropic media	6
1.1.3	Fluid-loaded solids	9
1.1.4	Piezoelectric effects	11
1.1.5	Scattering from layered cylinders	12
1.1.6	Elastic properties of composites	13
2	FIELD EQUATIONS AND TENSOR ANALYSIS	15
2.1	The stiffness tensor	16
2.2	Material symmetry	17
2.2.1	The transformation	17
2.3	Matrix forms of stiffness	21
2.4	Engineering constants	23
2.5	Transformed equations	24
2.5.1	Advantages of orthogonal transformations	25
2.6	Expanded field equations	26
2.6.1	Monoclinic	27
2.6.2	Orthotropic	28
2.7	Planes of symmetry	29
3	BULK WAVES	31
3.1	An overview	31
3.2	The Christoffel equation	33
3.2.1	General features of the Christoffel equation	34
3.2.2	Limitations of analytic solutions	37
3.3	Material symmetry	38
3.3.1	Analytical solutions	38
3.3.2	Higher symmetry	41

3.3.3	Cubic symmetry	42
3.3.4	The isotropic case	46
3.4	Computer aided analysis	48
3.5	Group velocity	54
3.6	Energy flux	58
4	GENERALIZED SNELL'S LAW AND INTERFACES	61
4.1	Boundary conditions	62
4.1.1	Types of interface conditions	62
4.2	Characterization of incident waves	64
4.3	Critical angles	66
4.4	Two fluid media	68
4.5	Two isotropic media	69
5	FORMAL SOLUTIONS	71
5.1	Common form of solutions	72
5.2	Triclinic layer	72
5.3	The monoclinic case	74
5.4	Higher symmetry materials	75
5.4.1	Propagation along off-principal-axes	77
5.4.2	Propagation along an axis of symmetry	77
5.4.3	Isotropic media	79
5.5	Formal solutions in fluid media	80
5.6	The $\alpha - c$ relation and the Christoffel equation	80
6	SCATTERED WAVE AMPLITUDES	83
6.1	Notation	84
6.2	Reflection from a free surface	85
6.3	Scattering from fluid-solid interfaces	88
6.4	Scattering from solid-solid interface	90
7	INTERFACE WAVES	93
7.1	Surface waves	94
7.2	Pseudo-surface waves	95
7.3	Scholte waves	99
8	FREE WAVE IN PLATES	103
8.1	Free waves in triclinic plates	105
8.2	Free waves in monoclinic plates	106
8.2.1	The dry case	106
8.2.2	Monoclinic plates immersed in fluids	108

8.2.3	Fluid-monoclinic plate-vacuum system	109
8.3	Higher symmetry material plates	110
8.4	Numerical computation strategy	112
9	GENERAL LAYERED MEDIA	117
9.1	Geometric description of unit cell	118
9.2	Analysis	118
9.2.1	The local transfer matrix	122
9.2.2	The global transfer matrix	123
9.3	Properties of the transfer matrix	124
9.4	Free waves on the layered cell	126
9.5	Waves in a periodic medium	127
9.5.1	Dispersion curves	128
9.5.2	Dispersive slownesses	129
9.5.3	Specialization to a single material	130
9.6	Bottom bounding solid substrate	131
10	PROPAGATION ALONG AXES OF SYMMETRY	135
10.1	Geometry	136
10.2	<i>SH</i> waves	137
10.2.1	Free waves	138
10.2.2	Periodic media	139
10.2.3	Effective elastic properties	143
10.3	Motion in the sagittal plane	145
10.4	Free waves on the layered cell	147
10.5	Waves in a periodic medium	148
10.6	Bottom bounding solid substrate	149
11	FLUID-LOADED SOLIDS	153
11.1	Reflection from a substrate	155
11.1.1	Qualitative discussion	157
11.2	Plates completely immersed in fluids	160
11.2.1	Cremer's correspondence principle	162
11.2.2	Fluid-plate-vacuum system	170
11.2.3	The general layered media	173
11.2.4	Bottom substrate	178
11.3	Higher symmetry cases	181
11.4	Leaky waves	183
11.4.1	Field of the incident finite beam	184
11.4.2	Field of the reflected beam	187
11.4.3	An overview of the reflection coefficient	188

11.4.4	Rayleigh pole	190
11.4.5	Reflected beam profile	193
11.5	Experimental technique	197
12	PIEZOELECTRIC EFFECTS	201
12.1	Basic relations of piezoelectric materials	202
12.2	Simplified field equations	203
12.3	Analysis	204
12.4	Formal solutions	205
12.4.1	Surface waves	207
12.4.2	Free plate modes	209
12.5	Higher symmetric materials	209
12.5.1	Orthotropic-222	210
12.5.2	B.-G. waves	211
12.6	Remarks on the monoclinic-m case	213
12.7	Reflection and transmission coefficients	213
12.7.1	Reflection and transmission from a substrate	214
12.7.2	Reflection and transmission from a plate	215
12.8	Sample illustrations	215
12.9	Remarks on layered piezoelectric media	218
13	TRANSIENT WAVES	221
13.1	Theoretical development	221
13.2	Source characterization	223
13.3	Integral transforms of formal solutions	225
13.3.1	Methods of inverting the transforms	229
13.4	Isotropic media	230
13.4.1	The Cagniard-de Hoop transformation	234
13.4.2	Displacement distribution	237
13.5	Anisotropic media	238
13.6	Cagniard-de Hoop transformation	239
13.6.1	Displacement solutions	242
13.7	Semi-space media	245
14	SCATTERING FROM LAYERED CYLINDERS	253
14.1	Field equations	255
14.2	Formal solutions in isotropic cylinders	256
14.3	Characterization of incident waves	258
14.4	Formal solutions for a layer	260
14.4.1	Local transfer matrix	262
14.4.2	Global transfer matrix	263

14.4.3	Properties of the transfer matrices	263
14.5	Scattering amplitudes	264
14.5.1	Scattering from a solid core	265
14.5.2	Scattering from an inner cavity	265
14.5.3	Stresses in the host medium	265
14.5.4	Scattering cross section	266
15	ELASTIC PROPERTIES OF COMPOSITES	267
15.1	General description of fibrous composites	267
15.2	The model	269
15.3	The layered model	269
15.3.1	Averaging	271
15.3.2	Strain and stress compatibilities	272
15.3.3	Analysis	272
15.4	The square fibrous case	275
15.4.1	Compatibilities	276
15.4.2	Analysis	277
15.5	Anisotropic fiber and matrix	279
15.5.1	The layered model	280
15.5.2	The fibrous case	281
15.6	Strain energy approach	282
15.6.1	The layered model	282
15.6.2	The fibrous model	284
15.7	Undulated fiber	284
15.7.1	Discretization	286
	Appendix	289
	References	295
	Additional References	315
	Subject Index	325
	Author Index	329