Contents

1 Introduction **1**
- 1.1 A Historical Background of Nonlinear Acoustics 3
- 1.2 A Historical Background of Fluid-Structure Interaction . . 4
- 1.3 Nonlinear Acoustics with Periodic Forcing 6
- 1.4 Fluid-Structure Interaction with Periodic Forcing 8

2 Preliminaries **9**
- 2.1 General Notation 10
- 2.2 Topology and differentiable structure 12
- 2.3 Fourier Transform and Multiplier Theory 14
- 2.4 Sobolev and Bessel Potential Spaces 15
  - 2.4.1 Functions on Spatial Domains 16
  - 2.4.2 Functions on Time-Space Domains 17
  - 2.4.3 Spaces of Solenoidal Functions 19
- 2.5 Interpolation 19
- 2.6 Embedding and Trace properties of Time-Periodic Sobolev spaces 24
  - 2.6.1 Embedding Properties 24
  - 2.6.2 Trace Space Operators 33
- 2.7 Mathematical Tools from Fluid Mechanics 35
  - 2.7.1 Poincaré's Inequality in Layer Domains 35
  - 2.7.2 Solenoidal Vector Fields and the Divergence Problem 37

3 Nonlinear Acoustics **39**
- 3.1 Models 41
- 3.2 The Damped Wave Equation 44
  - 3.2.1 The Steady State Damped Wave Equation 46
  - 3.2.2 The Purely Oscillatory Damped Wave Equation in the Whole Space 49
  - 3.2.3 The Purely Oscillatory Damped Wave Equation in the Half Space 54
  - 3.2.4 The Purely Oscillatory Damped Wave Equation in a Bounded Domain 57

3.2.5 The Time-Periodic Damped Wave Equation 66
3.3 The Kuznetsov Equation 69
3.4 The Blackstock-Crighton Equation 74
3.4.1 The Linearized Blackstock-Crighton Equation . . . 77
3.4.2 The Nonlinear Problem 82

4 Fluid-Structure Interaction **87**
4.1 Viscous Fluid Flow on an Elastic Plate 90
4.2 Reformulation in a Reference Configuration 93
4.3 Uniqueness 96
4.4 The Time-Periodic Stokes Equations 100
4.4.1 The Stokes System in the Half Space 102
4.4.2 The Stokes System in the Periodic Half Space . . . 115
4.5 The Coupled Resolvent Problem 119
4.6 A priori Estimates 129
4.6.1 The Periodic Half Space 129
4.6.2 Estimates of the Pressure Field 135
4.6.3 The Periodic Layer 139
4.7 The Stationary Linear System 145
4.7.1 The Stationary Stokes System 145
4.7.2 The Bi-Laplacian 147
4.7.3 The Stationary Linearized Fluid-Structure System . 148
4.8 The Linear Fluid-Structure Problem 150
4.8.1 The Linearized Fluid-Structure Problem with Homogeneous Divergence 151
4.8.2 The Fully Inhomogeneous Fluid-Structure System . 152
4.9 The Nonlinear Problem 155

Appendix **165**
A.1 Some Bounded Functions 165
A.1.1 Functions in the Context of Nonlinear Acoustics . . 165
A.1.2 Functions in the Context of Fluid-Structure Interaction 167
A.2 Fourier Multiplier 167
A.2.1 Higher Order Partial Derivatives of Fractions 168
A.2.2 Fourier Multiplier in the Whole Space 169
A.2.3 Fourier Multiplier on the Torus Group 173