Contents

1 The Fluid Dynamics Adventure, from Newton to Stokes via Cauchy, Euler, Navier, Poisson, and Fourier .......................... 1
  1.1 From Newton’s Fundamental Equation to the Cauchy Stress Principle and the Macroscopic Equations of Continuum Mechanics .................................................. 1
  1.2 Euler Non-viscous Equations and Navier Viscous Incompressible Equations .......................................................... 5
    1.2.1 Euler Non-viscous Case ........................................ 5
    1.2.2 Navier Viscous Incompressible Case ....................... 12
  1.3 Stokes’ Concept of Fluidity: Cauchy-Poisson and Fourier Constitutive Laws ................................................................. 15
    1.3.1 Stokes’ Four Postulates ....................................... 16
    1.3.2 Cauchy-Poisson Law for the Cauchy Stress Tensor ........ 17
    1.3.3 Fourier Law for the Heat Flux Vector ........................ 18
  1.4 Some Remarks ..................................................... 18
References ........................................................................... 26

Part I Classical Analytical-Asymptotics Newtonian NSF Fluid Dynamics

2 Formulation of Some NSF Unsteady Initial-Boundary Value Problems ................................................................................. 29
  2.1 The Case of a Thermally Perfect Gas: Typical NSF Equations .......... 30
  2.2 The Case of an Expansible Liquid ........................................ 31
  2.3 Navier-Stokes (NS) Barotropic Compressible Equations .............. 32
  2.4 The Case of Nonlinear Acoustics ......................................... 33
  2.5 Initial-Boundary Value Problem for the Typical NSF Equations .... 35
  2.6 The Rotating Earth and Its Atmosphere as a Continuum ............ 37
    2.6.1 The Rotating Earth ............................................. 38
    2.6.2 The Atmosphere as a Continuum ............................. 40
    2.6.3 Shallow Boussinesq Equations ............................... 42
    2.6.4 Deep Equations “à la Zeytounian” ........................... 44
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.3</td>
<td>Meteo-fluid Dynamics Models, and Fig. 6.3</td>
<td>123</td>
</tr>
<tr>
<td>6.4</td>
<td>The Three Significant Models of the Bénard Problem and Figs. 6.4 and 6.5</td>
<td>125</td>
</tr>
<tr>
<td>7</td>
<td>Some Concluding Remarks About Part II</td>
<td>133</td>
</tr>
<tr>
<td>7.1</td>
<td>Low Reynolds Number Case</td>
<td>133</td>
</tr>
<tr>
<td>7.2</td>
<td>Low Mach Number Case</td>
<td>133</td>
</tr>
<tr>
<td>7.3</td>
<td>Triple-Deck Model</td>
<td>134</td>
</tr>
<tr>
<td>7.4</td>
<td>Couette-Taylor Problem</td>
<td>136</td>
</tr>
<tr>
<td>7.5</td>
<td>Meteo–Fluid Dynamics</td>
<td>137</td>
</tr>
<tr>
<td>7.6</td>
<td>Some Complementary Remarks</td>
<td>139</td>
</tr>
<tr>
<td></td>
<td>Reference</td>
<td>140</td>
</tr>
<tr>
<td>Part III</td>
<td>Miscellaneous: Various Fluid Dynamics Workings Models</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Some Applications of the RAM Approach During the Years 1974–2014</td>
<td>143</td>
</tr>
<tr>
<td>8.1</td>
<td>Introduction</td>
<td>143</td>
</tr>
<tr>
<td>8.2</td>
<td>Turbomachinery Homogenized Flows</td>
<td>148</td>
</tr>
<tr>
<td>8.3</td>
<td>Asymptotic Modelling of Rolled-Up Vortex Sheets</td>
<td>154</td>
</tr>
<tr>
<td>8.4</td>
<td>Long Nonlinear Surface Waves on Water and Soliton</td>
<td>160</td>
</tr>
<tr>
<td>8.5</td>
<td>Pivotal Dimensionless Problem and the 2D Single Equation à la Boussinesq</td>
<td>161</td>
</tr>
<tr>
<td></td>
<td>Solitary and Cnoidal Waves</td>
<td>162</td>
</tr>
<tr>
<td>8.6</td>
<td>KdV and KP Equations for Weakly Nonlinear Long Waves in Shallow Water</td>
<td>163</td>
</tr>
<tr>
<td>8.7</td>
<td>Nonlinear Schrödinger (NLS) Equations and Schrödinger-Poisson (NLS-P) Equations</td>
<td>166</td>
</tr>
<tr>
<td>8.8</td>
<td>Some Final Remarks</td>
<td>168</td>
</tr>
</tbody>
</table>
8.5 Some Singular Aspects of the Blasius Bl Problem Asymptotics
of the Blasius Bl Steady Incompressible 2D Problem .............. 169
8.5.1 Formulation of a Steady Compressible 2D Viscous
Blasius Bl Problem ........................................... 170
8.5.2 Limit Euler (Outer) Equations for \((M_\infty)^2 \to 0, \)
with \(x\) and \(y\) Fixed ........................................... 171
8.5.3 Limit Prandtl (Inner) Equations for \((M_\infty)^2 \to 0, \)
with \(x\) and \(\eta = y/(M_\infty)^2\) Fixed ............................ 171
8.5.4 Flow Due to Displacement Thickness .......................... 172
8.5.5 Limit BL 2D Steady Equations Due to a Slight
Compressibility Effect ........................................... 172
8.6 A Theory for Lee Waves Downstream of a Mountain .......... 174
8.6.1 2D Steady Model Equations for Lee Waves ................. 174
8.6.2 Isochoric Case ............................................. 175
8.6.3 Boussinesq Case .......................................... 176
8.6.4 From the Isochoric Case to the Boussinesq Case ......... 177
8.6.5 Some Results Concerning the Problem (8.44b)–(8.44c) .... 177
8.6.6 Models for Steady 2D Non-viscous Lee Waves
in a Baroclinic Compressible Troposphere .................... 181
8.6.7 Four Limiting Cases ....................................... 186
8.7 A Model Problem for a Local Thermal Spot Effect ............. 187
8.7.1 Dimensionless Local Problem ................................ 187
8.7.2 Triple Deck Structure ...................................... 189
8.7.3 Analysis of the Three Regions .............................. 190
8.8 Flow of a Thin Film Over a Rotating Disk ....................... 193
8.8.1 A Mathematical Formulation ................................ 195
8.8.2 The Reduced Initial Boundary-Value Problem à la von
Karman .......................................................... 196
8.8.3 Dimensionless RAM Approach .............................. 196
8.8.4 Outer Long Time Scale Limit: \(Re \to 0\) with \(\tau\)
and \(\xi\) Fixed Zero-Order Outer Problem ....................... 197
8.8.5 First-Order Outer Problem ................................ 198
8.8.6 Inner Short Time Scale Analysis ............................ 198
8.8.7 Zero-Order Local Short Time Scale Problem .............. 198
8.8.8 Complementary Remarks ................................... 199
8.9 The KZK–Parabolic Single Model Equation in Nonlinear
Acoustics ......................................................... 200
8.9.1 The RAM Approach ....................................... 201
8.9.2 Leading Order System for \(U_0\) in the Simplistic Tentative
Expansion (8.78f) .............................................. 202
8.9.3 Second-Order System for \(U_1\) .............................. 203
8.9.4 The Compatibility-Non-Secularity Condition .............. 204
8.9.5 KZK Equation ............................................. 204
References ....................................................... 205
9 Some Concluding Remarks about Part III ........................................ 207
  9.1 RAM Approach ......................................................... 207
  9.2 Hydrodynamic Stability Theory ...................................... 208
  9.3 Bénard Thermal Convection .......................................... 209
  9.4 Anelastic (Deep) Equations .......................................... 209
  9.5 Small-Mach-Number Time-Dependent NSF Models ............... 213
  9.6 Analysis of Through-Flow Equations ............................. 215
  References ........................................................................ 217

Epilogue .............................................................................. 219

Index .................................................................................. 223
Challenges in Fluid Dynamics
A New Approach
Zeytounian, R.K.
2017, XXVI, 230 p. 38 illus., Hardcover
ISBN: 978-3-319-31618-5