

Springer Series in Computational Physics

Demetri P. Telionis

**Unsteady
Viscous Flows**



Springer-Verlag New York Heidelberg Berlin

Demetri P. Telionis

Unsteady Viscous Flows

With 132 Illustrations



Springer-Verlag
New York Heidelberg Berlin

Contents

Introduction	xv
Chapter 1. Basic Concepts	1
1.1 Introduction	1
1.2 The Governing Equations	2
1.3 Characteristics	6
1.4 Subcharacteristics	10
1.5 Navier–Stokes versus Euler and Prandtl	16
1.6 Zones of Influence and Dependence	21
1.7 Existence, Uniqueness, and Bounds	25
References	29
Chapter 2. Numerical Analysis	30
2.1 Introduction	30
2.2 Convergence	33
2.3 Stability	37
2.4 Consistency and the Equivalence Theorem	42
2.5 Unsteady Flow Equations	44
2.6 Implicit Schemes	49
2.7 The Keller–Box Method	53
2.8 Upwind Differencing	56
2.9 Navier–Stokes—Lattices and Boundary Conditions	66
References	76
Chapter 3. Impulsive Motion	79
3.1 Introduction	79
3.2 The Flow Immediately after an Impulsive Start	80
3.3 An Order of Magnitude Analysis	86
3.4 Infinite Bodies—Rayleigh Problems	89
3.5 Pointed Bodies Started Impulsively	92

3.6	Blunt Bodies Started Impulsively	102
3.7	Solutions to the Full Navier–Stokes Equations.	110
3.8	Results and Physical Interpretation	125
3.9	A Computer Program	133
	References	151
Chapter 4. Oscillations with Zero Mean		154
4.1	Introduction	154
4.2	Oscillations of an Infinite Flat Plate	156
4.3	Oscillations of a Blunt Body	158
4.4	The Streaming Layer	164
4.5	Inner and Outer Expansions	167
4.6	Typical Results	172
	References	184
Chapter 5. Oscillating Flows with Non-Vanishing Mean		186
5.1	Introduction	186
5.2	Perturbation Methods	187
5.3	The Method of Averaging.	191
5.4	The Boundary Layer Approximation	193
5.5	Numerical Results and Their Physical Significance	199
5.6	Nonlinear Effects	209
5.7	Traveling Waves	215
	References	220
Chapter 6. Unsteady Turbulent Flows		222
6.1	Introduction	222
6.2	The Triple Decomposition	224
6.3	Algebraic Models	230
6.4	One- and Two-Equation Models	236
6.5	Numerical Results and Experimental Data	244
6.6	A Computer Program	257
	References	276
Chapter 7. Unsteady Separation		279
7.1	Introduction	279
7.2	Separation over Moving Walls	286
7.3	Asymptotic Methods	295

7.4 Semisimilar Solutions 306

7.5 Direct Numerical Integration—Impulsive and Transient
Changes. 311

7.6 Lagrangian Formulation 317

7.7 The Emergence of Separation 320

7.8 Wakes 327

7.9 A Computer Program 336

References 404

Index 406