

Contents

Preface xi

Chapter 1

Introduction 3

- 1.1 Preliminary Remarks 3
- 1.2 History and Scope of Fluid Mechanics 4
- 1.3 Problem-Solving Techniques 5
- 1.4 The Concept of a Fluid 6
- 1.5 The Fluid as a Continuum 8
- 1.6 Dimensions and Units 9
- 1.7 Properties of the Velocity Field 17
- 1.8 Thermodynamic Properties of a Fluid 18
- 1.9 Viscosity and Other Secondary Properties 25
- 1.10 Basic Flow Analysis Techniques 40
- 1.11 Flow Patterns: Streamlines, Streaklines, and Pathlines 40
- 1.12 The Engineering Equation Solver 45
- 1.13 Uncertainty in Experimental Data 46
 - Problems 47
 - Additional Practice Problems 57
 - Comprehensive Problems 57
 - References 60

Chapter 2

Pressure Distribution in a Fluid 63

- 2.1 Pressure and Pressure Gradient 63
- 2.2 Equilibrium of a Fluid Element 65
- 2.3 Hydrostatic Pressure Distributions 66
- 2.4 Application to Manometry 73
- 2.5 Hydrostatic Forces on Plane Surfaces 76

- 2.6 Hydrostatic Forces on Curved Surfaces 84
- 2.7 Hydrostatic Forces in Layered Fluids 87
- 2.8 Buoyancy and Stability 89
- 2.9 Pressure Distribution in Rigid-Body Motion 95
- 2.10 Pressure Measurement 103
 - Summary 107
 - Problems 107
 - Word Problems 130
 - Additional Practice Problems 130
 - Comprehensive Problems 131
 - Design Projects 133
 - References 134

Chapter 3

Integral Relations for a Control Volume 137

- 3.1 Basic Physical Laws of Fluid Mechanics 137
- 3.2 The Reynolds Transport Theorem 141
- 3.3 Conservation of Mass 148
- 3.4 The Linear Momentum Equation 153
- 3.5 The Angular Momentum Theorem 167
- 3.6 The Energy Equation 172
- 3.7 Frictionless Flow: The Bernoulli Equation 183
 - Summary 192
 - Problems 193
 - Word Problems 220
 - Additional Practice Problems 221
 - Comprehensive Problems 222
 - Design Project 223
 - References 223

Chapter 4

Differential Relations for Fluid Flow 225

- 4.1 The Acceleration Field of a Fluid 226
- 4.2 The Differential Equation of Mass Conservation 227
- 4.3 The Differential Equation of Linear Momentum 234
- 4.4 The Differential Equation of Angular Momentum 240
- 4.5 The Differential Equation of Energy 242
- 4.6 Boundary Conditions for the Basic Equations 244
- 4.7 The Stream Function 249
- 4.8 Vorticity and Irrotationality 257
- 4.9 Frictionless Irrotational Flows 259
- 4.10 Some Illustrative Incompressible Viscous Flows 264
 - Summary 272
 - Problems 273
 - Word Problems 283
 - Additional Practice Problems 284
 - Comprehensive Problems 284
 - References 285

Chapter 5

Dimensional Analysis and Similarity 287

- 5.1 Introduction 287
- 5.2 The Principle of Dimensional Homogeneity 290
- 5.3 The Pi Theorem 296
- 5.4 Nondimensionalization of the Basic Equations 306
- 5.5 Modeling and Its Pitfalls 315
 - Summary 327
 - Problems 327
 - Word Problems 336
 - Additional Practice Problems 336
 - Comprehensive Problems 337
 - Design Projects 338
 - References 338

Chapter 6

Viscous Flow in Ducts 341

- 6.1 Reynolds Number Regimes 341

- 6.2 Internal versus External Viscous Flow 346
- 6.3 Head Loss—The Friction Factor 349
- 6.4 Laminar Fully Developed Pipe Flow 351
- 6.5 Turbulence Modeling 353
- 6.6 Turbulent Pipe Flow 359
- 6.7 Four Types of Pipe Flow Problems 367
- 6.8 Flow in Noncircular Ducts 373
- 6.9 Minor Losses in Pipe Systems 382
- 6.10 Multiple-Pipe Systems 391
- 6.11 Experimental Duct Flows: Diffuser Performance 397
- 6.12 Fluid Meters 402
 - Summary 423
 - Problems 424
 - Word Problems 442
 - Additional Practice Problems 443
 - Comprehensive Problems 443
 - Design Projects 445
 - References 446

Chapter 7

Flow Past Immersed Bodies 449

- 7.1 Reynolds Number and Geometry Effects 449
- 7.2 Momentum Integral Estimates 453
- 7.3 The Boundary Layer Equations 456
- 7.4 The Flat-Plate Boundary Layer 459
- 7.5 Boundary Layers with Pressure Gradient 468
- 7.6 Experimental External Flows 474
 - Summary 501
 - Problems 501
 - Word Problems 515
 - Additional Practice Problems 515
 - Comprehensive Problems 516
 - Design Projects 517
 - References 518

Chapter 8

Potential Flow and Computational Fluid Dynamics 521

- 8.1 Introduction and Review 521
- 8.2 Elementary Plane Flow Solutions 524
- 8.3 Superposition of Plane Flow Solutions 531
- 8.4 Plane Flow past Closed-Body Shapes 537

- 8.5** Other Plane Potential Flows 547
- 8.6** Images 551
- 8.7** Airfoil Theory 554
- 8.8** Axisymmetric Potential Flow 566
- 8.9** Numerical Analysis 571
 - Summary 585
 - Problems 586
 - Word Problems 596
 - Comprehensive Problems 597
 - Design Projects 598
 - References 598

Chapter 9

Compressible Flow 601

- 9.1** Introduction: Review of Thermodynamics 601
- 9.2** The Speed of Sound 606
- 9.3** Adiabatic and Isentropic Steady Flow 608
- 9.4** Isentropic Flow with Area Changes 614
- 9.5** The Normal Shock Wave 621
- 9.6** Operation of Converging and Diverging Nozzles 629
- 9.7** Compressible Duct Flow with Friction 634
- 9.8** Frictionless Duct Flow with Heat Transfer 646
- 9.9** Two-Dimensional Supersonic Flow 651
- 9.10** Prandtl-Meyer Expansion Waves 661
 - Summary 673
 - Problems 674
 - Word Problems 687
 - Additional Practice Problems 688
 - Comprehensive Problems 688
 - Design Projects 690
 - References 690

Chapter 10

Turbomachinery 693

- 10.1** Introduction and Classification 693
- 10.2** The Centrifugal Pump 696
- 10.3** Pump Performance Curves and Similarity Rules 702
- 10.4** Mixed- and Axial-Flow Pumps: The Specific Speed 712
- 10.5** Matching Pumps to System Characteristics 719
- 10.6** Turbines 726
 - Summary 740
 - Problems 740
 - Word Problems 751
 - Comprehensive Problems 752
 - Design Projects 753
 - References 754

Appendix A Physical Properties of Fluids 756

Appendix B Compressible Flow Tables 761

Appendix C Conversion Factors 770

Appendix D Equations of Motion in Cylindrical Coordinates 772

Answers to Selected Problems 774

Index 781