

Contents

Preface	ii	2.5	Hydrostatic Forces on Plane Surfaces	78
Chapter 1		2.6	Hydrostatic Forces on Curved Surfaces	84
Introduction	3	2.7	Hydrostatic Forces in Layered Fluids	86
1.1	Preliminary Remarks	2.8	Buoyancy and Stability	89
1.2	The Concept of a Fluid	2.9	Pressure Distribution in Rigid-Body Motion	94
1.3	The Fluid as a Continuum	2.10	Pressure Measurement	102
1.4	Dimensions and Units		Summary	106
1.5	Properties of the Velocity Field		Problems	106
1.6	Thermodynamic Properties of a Fluid		Word Problems	128
1.7	Viscosity and Other Secondary Properties		Fundamentals of Engineering Exam Problems	129
1.8	Basic Flow Analysis Techniques		Comprehensive Problems	130
1.9	Flow Patterns: Streamlines, Streaklines, and Pathlines		Design Projects	131
1.10	The Engineering Equation Solver		References	132
1.11	Uncertainty of Experimental Data			
1.12	The Fundamentals of Engineering (FE) Examination	Chapter 3		
1.13	Problem-Solving Techniques	Integral Relations for a Control Volume		135
1.14	History and Scope of Fluid Mechanics	3.1	Basic Physical Laws of Fluid Mechanics	135
	Problems	3.2	The Reynolds Transport Theorem	139
	Fundamentals of Engineering Exam Problems	3.3	Conservation of Mass	147
	Comprehensive Problems	3.4	The Linear Momentum Equation	153
	References	3.5	The Angular Momentum Theorem	166
		3.6	The Energy Equation	172
Chapter 2		3.7	Frictionless Flow: The Bernoulli Equation	182
Pressure Distribution in a Fluid	63		Summary	191
2.1	Pressure and Pressure Gradient		Problems	192
2.2	Equilibrium of a Fluid Element		Word Problems	220
2.3	Hydrostatic Pressure Distributions		Fundamentals of Engineering Exam Problems	221
2.4	Application to Manometry		Comprehensive Problems	222
			Design Project	223
			References	223

Chapter 4**Differential Relations for Fluid Flow 225**

- 4.1 The Acceleration Field of a Fluid 225
- 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 Plane Potential Flows 264
- 4.11 Some Illustrative Incompressible Viscous Flows 269
 - Summary 273
 - Problems 278
 - Word Problems 288
 - Fundamentals of Engineering Exam Problems 289
 - Comprehensive Problems 289
 - References 290

Chapter 5**Dimensional Analysis and Similarity 293**

- 5.1 Introduction 293
- 5.2 The Principle of Dimensional Homogeneity 296
- 5.3 The Pi Theorem 302
- 5.4 Nondimensionalization of the Basic Equations 309
- 5.5 Modeling and Its Pitfalls 318
 - Summary 328
 - Problems 329
 - Word Problems 337
 - Fundamentals of Engineering Exam Problems 337
 - Comprehensive Problems 338
 - Design Projects 339
 - References 340

Chapter 6**Viscous Flow in Ducts 343**

- 6.1 Reynolds Number Regimes 343
- 6.2 Internal versus External Viscous Flows 348
- 6.3 Head Loss—The Friction Factor 351
- 6.4 Laminar Fully Developed Pipe Flow 353

- 6.5 Turbulence Modeling 355
- 6.6 Turbulent Pipe Flow 361
- 6.7 Three Types of Pipe Flow Problems 369
- 6.8 Flow in Noncircular Ducts 375
- 6.9 Minor Losses in Pipe Systems 384
- 6.10 Multiple-Pipe Systems 393
- 6.11 Experimental Duct Flows: Diffuser Performance 399
- 6.12 Fluid Meters 404
 - Summary 425
 - Problems 426
 - Word Problems 443
 - Fundamentals of Engineering Exam Problems 444
 - Comprehensive Problems 445
 - Design Projects 447
 - References 447

Chapter 7**Flow Past Immersed Bodies 451**

- 7.1 Reynolds Number and Geometry Effects 451
- 7.2 Momentum Integral Estimates 455
- 7.3 The Boundary Layer Equations 458
- 7.4 The Flat-Plate Boundary Layer 461
- 7.5 Boundary Layers with Pressure Gradient 470
- 7.6 Experimental External Flows 476
 - Summary 503
 - Problems 503
 - Word Problems 516
 - Fundamentals of Engineering Exam Problems 517
 - Comprehensive Problems 517
 - Design Project 518
 - References 519

Chapter 8**Potential Flow and Computational Fluid Dynamics 523**

- 8.1 Introduction and Review 523
- 8.2 Elementary Plane Flow Solutions 526
- 8.3 Superposition of Plane Flow Solutions 528
- 8.4 Plane Flow past Closed-Body Shapes 535
- 8.5 Other Plane Potential Flows 544
- 8.6 Images 549
- 8.7 Airfoil Theory 551
- 8.8 Axisymmetric Potential Flow 563

8.9	Numerical Analysis	568	10.7	Flow Measurement and Control by Weirs	724
	Summary	583		Summary	731
	Problems	583		Problems	731
	Word Problems	594		Word Problems	742
	Comprehensive Problems	594		Fundamentals of Engineering Exam Problems	743
	Design Projects	596		Comprehensive Problems	743
	References	596		Design Projects	744
				References	745
Chapter 9					
Compressible Flow 599					
9.1	Introduction	599	Chapter 11		
9.2	The Speed of Sound	604	Turbomachinery 747		
9.3	Adiabatic and Isentropic Steady Flow	606	11.1	Introduction and Classification	747
9.4	Isentropic Flow with Area Changes	612	11.2	The Centrifugal Pump	750
9.5	The Normal Shock Wave	619	11.3	Pump Performance Curves and Similarity Rules	756
9.6	Operation of Converging and Diverging Nozzles	627	11.4	Mixed- and Axial-Flow Pumps: The Specific Speed	766
9.7	Compressible Duct Flow with Friction	632	11.5	Matching Pumps to System Characteristics	772
9.8	Frictionless Duct Flow with Heat Transfer	644	11.6	Turbines	779
9.9	Two-Dimensional Supersonic Flow	649		Summary	792
9.10	Prandtl-Meyer Expansion Waves	659		Problems	793
	Summary	671		Word Problems	804
	Problems	672		Comprehensive Problems	804
	Word Problems	685		Design Project	806
	Fundamentals of Engineering Exam Problems	685		References	806
	Comprehensive Problems	686	Appendix A	Physical Properties of Fluids	808
	Design Projects	687	Appendix B	Compressible Flow Tables	813
	References	688	Appendix C	Conversion Factors	830
Chapter 10					
Open-Channel Flow 691					
10.1	Introduction	691	Appendix D	Equations of Motion in Cylindrical Coordinates	832
10.2	Uniform Flow; The Chézy Formula	697	Appendix E	Introduction to EES	834
10.3	Efficient Uniform-Flow Channels	702	Answers to Selected Problems	846	
10.4	Specific Energy; Critical Depth	704	Index	853	
10.5	The Hydraulic Jump	711			
10.6	Gradually Varied Flow	716			