Contents

Preface v

1. Basic Concepts of Fluid Mechanics 1

1.1 Introduction 1
1.2 Characteristics of a Fluid 1
1.3 Kinds of Fluids 4
1.4 Fluid Property Definitions 4
1.5 Thermodynamic Concepts 14
1.6 Other Fluid Properties 18
References

2. Fluid Statics 24

2.1 Introduction 24
2.2 Fluid Statics 24
2.3 Basic Equation of Fluid Statics 25
2.4 Pressure- Height Relations for Incompressible Fluids 27
2.5 Pressure -Sensing Devices 27
2.6 Pressure–Height Relations for Ideal Gases 33
2.7 Atmosphere 35
2.8 Buoyancy and Flotation 36

3. Equations of Fluid Motion **42**

3.1 Introduction 42
3.2 Fluid Kinematics 42
3.3 Fluid Dynamics 46
3.4 Gas Dynamics 65

4. Flow in Pipes **140**

4.1 Introduction 140
4.2 Background 140
4.3 Physical Analysis for Incompressible Flow 141
4.4 Dynamic Similarity for Incompressible Flow 142
4.5 Reynolds Number Equations 143
4.6 Laminar Flow in Pipes 144
4.7 Turbulent Flow in Pipes 148
4.8 Energy Losses in Piping Systems 150
4.9 Design Velocities 160
4.10 Engineering Design Calculations 162
4.11 Recommended Procedures for Design Calculations 163
4.12 Compressible Flow in Pipes 180
4.13 Noncircular Pipes 188
4.14 Hazen-Williams Equation 190
References 194

5. Flow in Open Channels **196**

5.1 Introduction 196
5.2 Background 196
5.3 Definitions 197
5.4 Parameter for Open Channel Flow 198
5.5 Maximum Hydraulic Radius 201
5.6 Specific Energy 203
5.7 Hydraulic Jump 208
5.8 Weirs 211
5.9 Rectangular Weirs 212
5.10 Triangular Weirs 215
References 218

6. Flow Measurement in Closed Conduits **219**

6.1 Introduction 219
6.2 Background 219
6.3 Flow Measurement Accuracy 220

6.4 Dimensional Analysis of Pipeline Flow Meters 220
6.5 Physical Analysis of Pipeline Flow Meters 220
6.6 ASME Venturi Tubes 222
6.7 ASME Flow Nozzles 229
6.8 ASME Orifice Meters 236
6.9 Elbow Flow Meters 244
6.10 Pitot Tubes 248
6.11 ASME Critical Flow Venturi Nozzles 254
References 259

7. Forces on Immersed Objects 261

7.1 Introduction 261
7.2 Background 261
7.3 Drag and Lift 262
7.4 Skin Friction Drag 265
7.5 Shape Drag 268
7.6 Drag of a Sphere 270
7.7 Drag of a Cylinder 275
7.8 Wake Frequency 278
7.9 Resistance of Ships 281
7.10 Lifting Vanes 283
7.11 Propeller Characteristics 287

8. Unsteady Flow 291

8.1 Introduction 291
8.2 Background 291
8.3 Equation of Motion 291
8.4 One-Dimensional Equation of Motion 293
8.5 Unsteady Incompressible Flow in Closed Conduits 294
8.6 Establishment of Steady Flow 295
8.7 Velocity of Pressure Waves in Pipes 296
8.8 Water Hammer 299
8.9 Time to Change Tank Levels with Inflow 303
8.10 Time to Change Tank Levels Without Inflow 306
Reference 308

Appendix A Conversion Factors *309*
Appendix B Pipe Schedules *311*
Appendix C Properties of Areas, Pipes, and Tubing *313*
Appendix D Fluid Properties *333*
Index *389*