CONTENTS

CHAPTER 1 INTRODUCTION 1

1-1 Fluid mechanics in engineering curriculum, 1
1-2 Historical development of fluid mechanics, 2
1-3 Dimensions and units, 3
1-4 Physical properties of fluids and their influences on fluid motion, 4

CHAPTER 2 FLUID STATICS 7

2-1 Static fluid pressure, 7
2-2 Variation of pressure with elevation in a fluid, 8
2-3 Measurement of fluid pressure, 14
2-4 Hydrostatic forces on plane surfaces, 21
2-5 Hydrostatic forces on curved surfaces, 26
2-6 Buoyancy, 28
2-7 Stability of submerged and floating bodies, 31

CHAPTER 3 FLUID KINEMATICS 45

3-1 Fluid in motion, 45
3-2 Streamlines and stream tubes, 47
3-3 Principle of continuity—conservation of mass flow, 50
3-4 Two-dimensional planar flow, 52
3-5 Rotational and irrotational flow, 56
3-6 Stream functions, 58
3-7 Velocity potential functions, 61

3-8 The flow net analysis, 63
3-9 Accelerations in fluid motions, 67

CHAPTER 4 FLUID DYNAMICS 75

4-1 Dynamical equations of fluid motion, 75
4-2 One-dimensional Euler's equation and Bernoulli's equation, 78
4-3 Energy equation—conservation of energy, 80
4-4 Interpretation of Bernoulli's equation, 86
4-5 Energy equation and Bernoulli's equation for flow systems, 88
4-6 Applications of Bernoulli's equation, 93
4-7 Power of hydraulic machinery, 106
4-8 Pressure-velocity relationship, 108
4-9 Impulse-momentum equation—conservation of momentum, 112
4-10 Applications of the impulse-momentum equation, 115
4-11 Dynamics of confined liquid, 134
4-12 Vortex motion—flow in curved paths, 138

CHAPTER 5 FLUID VISCOSITY AND FLOW OF REAL FLUIDS 164

5-1 Characteristics of flow of real fluids, 164
5-2 Fluid viscosity and laminar motion of fluids, 168
5-3 Laminar flow of an incompressible fluid through straight channels with parallel boundaries, 174
5-4 Laminar flow of incompressible fluids in round pipes—Hagen-Poiseuille theory, 183
5-5 Reynolds dynamical similarity of flow of real fluids, 191
5-6 Transition between laminar and turbulent flow, 198
5-7 Fluid turbulence and statistical nature of the turbulent motion of fluids, 201
5-8 Semiempirical theories of turbulence, 203

CHAPTER 6 DIMENSIONAL ANALYSIS AND MODEL SIMILITUDE 214

6-1 The significance of dimensional analysis in fluid mechanics, 214
6-2 Dimensions and dimensional homogeneity, 215
6-3 Dimensional analysis, 217

6-4 The use of dimensional analysis in presenting experimental data, 225
6-5 Model similitude, 226

CHAPTER 7 FLOW OF INCOMPRESSIBLE FLUIDS IN CLOSED CONDUITS 235

7-1 Basic equations of friction loss in pipe flow, 235
7-2 Coefficient of friction in pipe flow and its physical significance, 237
7-3 Laminar flow in pipes, 240
7-4 Experimental results of turbulent flow in smooth pipes—power law, 243
7-5 Universal velocity distribution laws of turbulent pipe flow, 255
7-6 Velocity distribution of turbulent flow in smooth pipes, 261
7-7 Velocity distribution of turbulent flow in rough pipes, 269
7-8 Velocity distribution equations for turbulent flow in both smooth and rough pipes, 273
7-9 Universal resistance laws for turbulent pipe flow, 279
7-10 Resistance diagram for commercial pipes, 282
7-11 Turbulent flow in closed conduits of noncircular cross sections, 286
7-12 Minor losses in pipe lines, 290
7-13 Some pipe line problems, 298
7-14 Measurement of flow in pipe lines, 305

CHAPTER 8 FLUID COMPRESSIBILITY AND COMPRESSIBLE FLOW 320

8-1 Thermodynamic considerations of compressible flow, 320
8-2 Bulk modulus, 324
8-3 Sonic velocity, 325
8-4 Mach number and the dynamic similarity of compressible flow, 328
8-5 Basic equations of one-dimensional compressible flow, 329
8-6 Integrated equations for one-dimensional reversible adiabatic flow, 334
8-7 Effect of area variation on compressible flow, 338

8-8 Compressible flow in convergent-divergent passages, 340
8-9 One-dimensional shock fronts, 351
8-10 Compressible flows in constant-area pipes with friction, 356
8-11 Measurement of compressible flows, 365

CHAPTER 9 FLUID FLOW ABOUT IMMERSED BODIES 377

9-1 Fundamentals of resistance of immersed bodies, 377
9-2 Boundary layers and friction drag, 380
9-3 Laminar boundary layer, 385
9-4 Turbulent boundary layer, 390
9-5 Separation of boundary layer flow and pressure drag, 399
9-6 Drag coefficients, 406
9-7 Effect of fluid compressibility on the drag, 411

CHAPTER 10 DYNAMIC LIFT 420

10-1 Phenomena of dynamic lift, 420
10-2 Circulation, 422
10-3 Circulation theory of lift and the Magnus effect, 424
10-4 Origin of the circulation around an airfoil, 429
10-5 Lift coefficient of an airfoil, 431
10-6 Induced drag on an airfoil of finite length, 433
10-7 Effect of fluid compressibility on the lift, 438

CHAPTER 11 FLOW OF LIQUIDS IN OPEN CHANNELS 443

11-1 Basic considerations in open-channel flow, 443
11-2 Classification of open-channel flows, 445
11-3 Fundamental equations for uniform flows in open channels, 448
11-4 Velocity distribution in a cross section of an open channel, 456
11-5 Froude number and the dynamic similarity in the flow with free surface, 458
11-6 The concept of specific energy and the critical depth of flow in an open channel, 460
11-7 Occurrence of alternate depths in an open channel, 464
11-8 Gradually varied flow, 469

11-9 Measurement of flows in open channels, 472
11-10 Analogy between open-channel flow and compressible flow, 478

APPENDIX **485**

A-1 Approximate physical properties of liquids at 60°F and standard atmospheric pressure, 485
A-2 Physical properties of water at standard atmospheric pressure, 486
A-3 Physical properties of air at standard atmospheric pressure, 486
A-4 Properties of the ICAO Standard Atmosphere, 487
A-5 Conversion of units, 487