



Contents

CHAPTER 1

THE NATURE OF FLUIDS AND THE STUDY OF FLUID MECHANICS

1

1.1	The Big Picture	1
1.2	Objectives of This Chapter	3
1.3	Difference Between Liquids and Gases	3
1.4	Force and Mass	4
1.5	The International System of Units (SI)	4
1.6	The U.S. Customary System	6
1.7	Consistent Units in an Equation	7
1.8	The Definition of Pressure	10
1.9	Compressibility	12
1.10	Density, Specific Weight, and Specific Gravity	13
1.11	Surface Tension	17
	References	19
	Practice Problems	19
	Computer Programming Assignments	22

CHAPTER 2

VISCOSITY OF FLUIDS

25

2.1	The Big Picture	25
2.2	Objectives of This Chapter	26
2.3	Dynamic Viscosity	26
2.4	Kinematic Viscosity	28
2.5	Newtonian Fluids and Nonnewtonian Fluids	29
2.6	Variation of Viscosity with Temperature	30
2.7	Viscosity Measurement	31
2.8	SAE Viscosity Grades	36
2.9	ISO Viscosity Grades	39
2.10	Hydraulic Fluids for Fluid Power Systems	40
	References	42
	Practice Problems	42
	Computer Programming Assignments	44

CHAPTER 3		
PRESSURE MEASUREMENT		45
3.1	The Big Picture	45
3.2	Objectives	46
3.3	Absolute and Gage Pressure	46
3.4	Relationship Between Pressure and Elevation	48
3.5	Development of the Pressure-Elevation Relation	51
3.6	Pascal's Paradox	54
3.7	Manometers	55
3.8	Barometers	60
3.9	Pressure Gages and Transducers	61
3.10	Pressure Transducers	63
3.11	Pressure Expressed as the Height of a Column of Liquid	65
	References	66
	Practice Problems	66
CHAPTER 4		
FORCES DUE TO STATIC FLUIDS		75
4.1	The Big Picture	75
4.2	Objectives	77
4.3	Gases Under Pressure	77
4.4	Horizontal Flat Surfaces Under Liquids	78
4.5	Rectangular Walls	79
4.6	Submerged Plane Areas—General	82
4.7	Development of the General Procedure for Forces on Submerged Plane Areas	86
4.8	Piezometric Head	88
4.9	Distribution of Force on a Submerged Curved Surface	89
4.10	Effect of a Pressure Above the Fluid Surface	95
4.11	Forces on a Curved Surface with Fluid Below It	95
4.12	Forces on Curved Surfaces with Fluid Above and Below	97
	Practice Problems	97
	Computer Programming Assignments	113
CHAPTER 5		
BUOYANCY AND STABILITY		115
5.1	The Big Picture	115
5.2	Objectives	116
5.3	Buoyancy	117
5.4	Stability of Completely Submerged Bodies	125
5.5	Stability of Floating Bodies	126
5.6	Degree of Stability	131
	Reference	133
	Practice Problems	133
	Computer Programming Assignments	143

CHAPTER 6	
FLOW OF FLUIDS AND BERNOULLI'S EQUATION	145
6.1 The Big Picture	145
6.2 Objectives	147
6.3 Fluid Flow Rate and the Continuity Equation	147
6.4 Commercially Available Pipe and Tubing	151
6.5 Recommended Velocity of Flow in Pipe and Tubing	152
6.6 Flow in Noncircular Sections	156
6.7 Conservation of Energy—Bernoulli's Equation	157
6.8 Interpretation of Bernoulli's Equation	159
6.9 Restrictions on Bernoulli's Equation	161
6.10 Applications of Bernoulli's Equation	161
6.11 Torricelli's Theorem	171
6.12 Flow Due to a Falling Head	174
Reference	177
Practice Problems	177
Computer Programming Assignments	189

CHAPTER 7	
GENERAL ENERGY EQUATION	191
7.1 The Big Picture	191
7.2 Objectives	193
7.3 Energy Losses and Additions	193
7.4 Nomenclature of Energy Losses and Additions	196
7.5 General Energy Equation	196
7.6 Power Required by Pumps	201
7.7 Power Delivered to Fluid Motors	205
Practice Problems	207

CHAPTER 8	
REYNOLDS NUMBER, LAMINAR FLOW, AND TURBULENT FLOW	221
8.1 The Big Picture	221
8.2 Objectives	224
8.3 Reynolds Number	224
8.4 Critical Reynolds Numbers	225
8.5 Velocity Profiles	227
8.6 Hydraulic Radius for Noncircular Cross Sections	229
8.7 Reynolds Number for Closed, Noncircular Cross Sections	231
References	232
Practice Problems	232

CHAPTER 9	
ENERGY LOSSES DUE TO FRICTION	239
9.1 The Big Picture	239
9.2 Objectives	240
9.3 Darcy's Equation	240
9.4 Friction Loss in Laminar Flow	241
9.5 Friction Loss in Turbulent Flow	242
9.6 Equations for Friction Factor	250
9.7 Friction Loss in Noncircular Cross Sections	251
9.8 Velocity Profile for Turbulent Flow	252
9.9 Hazen-Williams Formula for Water Flow	255
9.10 Other Forms of the Hazen-Williams Formula	257
9.11 Nomograph for Solving Hazen-Williams Formula	257
References	259
Practice Problems	259
Computer Programming Assignments	267
CHAPTER 10	
MINOR LOSSES	269
10.1 The Big Picture	269
10.2 Objectives	271
10.3 Resistance Coefficient	271
10.4 Sudden Enlargement	272
10.5 Exit Loss	275
10.6 Gradual Enlargement	275
10.7 Sudden Contraction	278
10.8 Gradual Contraction	280
10.9 Entrance Loss	283
10.10 Resistance Coefficients for Valves and Fittings	284
10.11 Application of Standard Valves	289
10.12 Pipe Bends	293
10.13 Pressure Drop in Fluid Power Valves	295
10.14 Flow Coefficients for Valves Using C_v	300
References	301
Practice Problems	301
Computer-Aided Analysis and Design Assignments	306
CHAPTER 11	
SERIES PIPE LINE SYSTEMS	307
11.1 The Big Picture	307
11.2 Objectives	308
11.3 Class I Systems	308
11.4 Spreadsheet Aid for Class I Problems	314
11.5 Class II Systems	317
11.6 Class III Systems	325
References	330
Practice Problems	330

Practice Problems for Any Class	335
Computer Aided Analysis and Design Assignments	340

CHAPTER 12**PARALLEL PIPE LINE SYSTEMS 341**

12.1	The Big Picture	341
12.2	Objectives	343
12.3	Systems with Two Branches	344
12.4	Systems with Three or More Branches—Networks	351
	References	360
	Practice Problems	360
	Computer Programming Assignments	364

CHAPTER 13**PUMP SELECTION AND APPLICATION 365**

13.1	The Big Picture	365
13.2	Objectives	367
13.3	Parameters Involved in Pump Selection	368
13.4	Types of Pumps	368
13.5	Performance Data for Positive Displacement Pumps	377
13.6	Performance Data for Centrifugal Pumps	378
13.7	Affinity Laws for Centrifugal Pumps	379
13.8	Manufacturer's Data for Centrifugal Pumps	381
13.9	The Operating Point of a Pump and Pump Selection	390
13.10	Alternate System Operating Modes	396
13.11	Pump Selection and Specific Speed	397
13.12	Net Positive Suction Head	400
13.13	Suction Line Details	403
13.14	Discharge Line Details	404
	References	405
	Practice Problems	406
	Design Problems	408
	Comprehensive Design Problem	411

CHAPTER 14**OPEN CHANNEL FLOW 413**

14.1	The Big Picture	413
14.2	Objectives	414
14.3	Classification of Open Channel Flow	414
14.4	Hydraulic Radius and Reynolds Number in Open Channel Flow	417
14.5	Kinds of Open Channel Flow	417
14.6	Uniform Steady Flow in Open Channels	418
14.7	The Geometry of Typical Open Channels	423
14.8	The Most Efficient Shapes for Open Channels	426
14.9	Critical Flow and Specific Energy	427
14.10	Hydraulic Jump	429

References	432
Practice Problems	432
Computer Programming Assignments	434

CHAPTER 15**FLOW MEASUREMENT**

437

15.1	The Big Picture	437
15.2	Objectives	438
15.3	Flowmeter Selection Factors	438
15.4	Variable Head Meters	440
15.5	Variable Area Meters	448
15.6	Turbine Flowmeter	449
15.7	Vortex Flowmeter	450
15.8	Magnetic Flowmeter	450
15.9	Ultrasonic Flowmeters	452
15.10	Positive Displacement Meters	452
15.11	Mass Flow Measurement	452
15.12	Velocity Probes	455
15.13	Computer-Based Data Acquisition and Processing	460
15.14	Open Channel Flow Measurement	462
	References	464
	Review Questions	465
	Practice Problems	465
	Computer Programming Assignments	466

CHAPTER 16**FORCES DUE TO FLUIDS IN MOTION**

467

16.1	The Big Picture	467
16.2	Objectives	468
16.3	Force Equation	468
16.4	Impulse-Momentum Equation	469
16.5	Problem-Solving Method Using the Force Equations	469
16.6	Forces on Stationary Objects	470
16.7	Forces on Bends in Pipe Lines	473
16.8	Forces on Moving Objects	477
	Practice Problems	478

CHAPTER 17**DRAG AND LIFT**

485

17.1	The Big Picture	485
17.2	Objectives	486
17.3	Drag Force Equation	487
17.4	Pressure Drag	488
17.5	Drag Coefficient	489
17.6	Friction Drag on Spheres in Laminar Flow	495
17.7	Vehicle Drag	496
17.8	Compressibility Effects and Cavitation	498

17.9	Lift and Drag on Airfoils	499
	References	502
	Practice Problems	502

CHAPTER 18**FANS, BLOWERS, COMPRESSORS,
AND THE FLOW OF GASES** **507**

18.1	The Big Picture	507
18.2	Objectives	508
18.3	Gas Flow Rates and Pressures	508
18.4	Classification of Fans, Blowers, and Compressors	509
18.5	Flow of Compressed Air and Other Gases in Pipes	514
18.6	Flow of Air and Other Gases through Nozzles	521
	References	529
	Practice Problems	529
	Computer Programming Assignments	531

CHAPTER 19**FLOW OF AIR IN DUCTS** **533**

19.1	The Big Picture	533
19.2	Objectives	535
19.3	Energy Losses in Ducts	535
19.4	Duct Design Example	540
	References	546
	Practice Problems	546

APPENDIXES**551**

A	Properties of Water	551
B	Properties of Common Liquids	553
C	Typical Properties of Petroleum Lubricating Oils	555
D	Variation of Viscosity with Temperature	557
E	Properties of Air	561
F	Dimensions of Steel Pipe	565
G	Dimensions of Steel Tubing	567
H	Dimensions of Type K Copper Tubing	569
I	Dimensions of Ductile Iron Pipe	571
J	Areas of Circles	573
K	Conversion Factors	575
L	Properties of Areas	579
M	Properties of Solids	581
N	Gas Constant, Adiabatic Exponent, and Critical Pressure Ratio for Selected Gases	583

ANSWERS TO SELECTED PROBLEMS**585****INDEX****591**