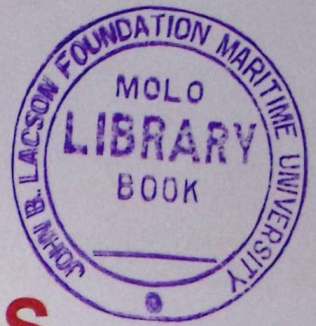




Fluid Mechanics

Artem Shlyakhov Marie-Magdeleine

TAP



FLUID MECHANICS

Artem Shlyakhov Marie-Magdeleine



Toronto Academic Press

Contents

<i>Preface</i>	<i>xix</i>
<i>List of Figures</i>	<i>ix</i>
<i>List of Tables</i>	<i>xv</i>
<i>List of Abbreviations</i>	<i>xvii</i>

1 Introduction to Fluid Mechanics 1

Unit Introduction	1
1.1. What Is Fluid?	3
1.2. Application Areas of Fluid Mechanics	7
1.3. The No-Slip Condition	8
1.4. History of Fluid Mechanics	10
1.5. Classification of Fluid Flows	15
1.5.1. Viscous versus Inviscid Regions of Flow	15
1.5.2. Internal versus External Flow	16
1.5.3. Laminar versus Turbulent Flow	17
1.5.4. Natural (or Unforced) versus Forced Flow	17
1.5.5. Steady versus Unsteady Flow	18
1.5.6. One-, Two-, and Three-Dimensional Flows	20
1.6. System and Control Volume	21
1.7. Importance of Dimensions and Units	22
1.8. Dimensional Homogeneity	24
1.9. Mathematical Modeling of Engineering Problems	24
1.10. Engineering Software Packages	26
1.11. Accuracy, Precision, and Significant Digits	29
Summary	30

Review Questions	30
Multiple Choice Questions	30
References	31

2 Properties of Fluids 41

Unit Introduction	41
2.1. Continuum	43
2.2. The Density of Ideal Gases	44
2.3. Vapor Pressure and Cavitation	44
2.4. Energy and Specific Heats	47
2.5. Viscosity	47
2.6. Surface Tension and Capillary Effect	49
2.7. Capillary Effect	50
Summary	52
Review Questions	52
Multiple Choice Questions	52
References	53

3 Pressure and Fluids Static 57

Unit Introduction	57
3.1. Pressure	59
3.2. The Manometer	62
3.3. Pressure Measuring Devices	64

3.4. The Barometer and Atmospheric Pressure	65	5.8. Acceleration of a Fluid Particle	114
3.5. Fluid Statics	67	5.9. Static, Dynamic, and Stagnation Pressures	115
3.6. Submerged Curved Surfaces With Hydrostatic Forces	67	5.10. Limitations on the Use of the Bernoulli Equation	118
3.7. Stability And Buoyancy	69	5.11. Hydraulic Grade Line (HGL) and Energy Grade Line (EGL)	121
3.8. Stability Of Submerged And Drifting Objects	70	5.12. General Energy Equation	123
3.9. In Rigid-Body Fluid Motion	74	Summary	127
Summary	76	Review Questions	127
Review Questions	76	Multiple Choice Questions	127
Multiple Choice Questions	76	References	128
References	77		

4 Fluid Kinematics 83

Unit Introduction	83
4.1. Lagrangian and Eulerian Descriptions	85
4.2. Fundamentals of Flow Visualization	88
4.3. Refractive Flow Visualization Techniques	89
4.4. Surface Flow Visualization Techniques	91
4.5. Plots of Fluid Flow Data	91
4.6. Other Kinematic Descriptions	96
4.7. The Reynolds Transport Theorem	97
Summary	100
Review Questions	100
Multiple Choice Questions	100
References	101

5 Mass, Bernoulli, and Energy Equations 107

Unit Introduction	107
5.1. Conservation of Mass	109
5.2. Conservation of Momentum	110
5.3. Conservation of Energy	110
5.4. Moving or Deforming Control Volumes	112
5.5. Mass Balance for Steady-Flow Processes	112
5.6. Mechanical Energy and Efficiency	113
5.7. The Bernoulli Equation	113

6 Flow Over Bodies 133

Unit Introduction	133
6.1. Drag and Lift	137
6.2. Friction and Pressure Drag	142
6.3. Reducing Drag by Streamlining	144
6.4. Flow Separation	147
6.5. Drag Coefficients of Common Geometries	149
6.6. Biological Systems and Drag	151
6.7. Drag Coefficients of Vehicles	152
6.8. Superposition	153
6.9. Parallel Flow Over Flat Plates	154
6.10. Friction Coefficient	156
6.11. Flow Over Spheres and Cylinders	157
6.12. Effect of Surface Roughness	160
6.13. Lift	160
6.14. End Effects of Wing Tips	165
Summary	167
Review Questions	167
Multiple Choice Questions	167
References	168

7 Turbomachinery 177

Unit Introduction	177
7.1. Classifications and Terminology	178
7.2. Pumps	181
7.3. Pump Performance Curves and Matching a Pump to a Piping System	183

7.4. Pump Cavitation and Net Positive Suction Head	184
7.5. Pumps In Series and Parallel	185
Summary	188
Review Questions	188
Multiple Choice Questions	188
References	189

8.3. Additional Equations of Motion	199
8.4. Grid Generation and Grid Independence	200
Summary	206
Review Questions	206
Multiple Choice Questions	206
References	207

8 Introduction to Computational Fluid Dynamics **193**

Unit Introduction	193
8.1. Equations of Motion	195
8.2. Solution Procedure	196

INDEX **211**

INDEX

A

Acceleration 13, 65, 66, 67, 74, 75, 87, 96, 101, 110, 113, 114, 115, 127, 132, 210
Accessibility 118
Adaptability 118
Aerodynamics 2, 36, 133, 152, 170, 193, 206
Aerostatics 67
Aircraft 8, 14, 133, 135, 137, 143, 148, 161, 164, 165, 166
Airflow 7, 21, 22, 208
Airplane 133, 139, 148, 161, 164, 165, 181
Algebraic 28, 78, 198
Algorithm 197, 199, 201, 204, 207
Analogy 74
Angular position 3
Angular speed 96
Arbitrary 22, 82, 99, 128
Arbitrary connection 99
Artificial heart 7
Assume uniform 99
Atmosphere 43, 44, 49, 51, 59, 60, 62, 64, 65, 76, 86, 90, 100, 125
Atmosphere pressure 43
Atomic structure 43
Attitude 1
Attributable 142, 152
Automatic gearbox 8
Axisymmetric 33, 135, 138, 172, 175

B

Barometer 57, 65, 80
Behavior 1, 5, 6, 15, 30, 33, 80, 100, 147, 149, 159
Behavior of fluid 1, 100
Bernoulli approximations 114
Bernoulli equation 107, 108, 113, 114, 115, 118, 119, 120, 121, 127, 128, 129, 130, 131, 132, 162, 206
Biomedical 8, 206
Blood circulation 133
Boundary layer 9, 15, 16, 35, 38, 56, 79, 92, 93, 94, 141, 144, 146, 148, 154, 155, 156, 157, 158, 159, 160, 162, 168, 197, 204
Buoyancy 11, 17, 70, 72, 73, 77, 78, 79, 80, 81, 89, 199

C

Capacity 3, 6, 14, 41, 54, 80, 124, 166, 181, 191
Capillary 13, 42, 50, 53, 54, 55, 56, 62
Capillary effect 50, 53, 54, 55, 56
Circuit 21, 64, 129
Circumstances 5, 18, 20, 26, 43, 47, 120, 140, 141, 157, 179, 183, 199, 205
Coefficient 19, 41, 47, 55, 113, 140, 141, 143, 144, 145, 146, 149, 150, 151, 152, 153, 154, 155, 157, 158, 159, 160, 164, 165, 168, 169, 170, 171, 172, 173
Collision 6, 15

212 Fluid Mechanics

Common safety practice 147
Communication 8
Complexity 14, 103
Compound 44, 56
Comprehensive distribution 139
compressing system 42
Compressor 7, 22, 66, 180, 188
Computational fluid dynamics (CFD) 28, 88, 95, 193, 194, 206, 210
Conference of Weights and Measures (CGPM) 23
Consequently 24, 118, 124, 145, 153, 196
Conservation 102, 104, 107, 109, 111, 123, 128, 130, 131, 132, 157, 179
Conserving of mass 109, 110, 111
Consistency 13, 88
Construction 8, 136, 177
Contemporary 94, 197, 200, 201
Continuum 30, 42, 43, 53, 54, 55, 56, 103, 107, 113
Controller permits 97
Control surfaces 97
Control volume 22, 30, 83, 98, 104, 110, 111, 112
Control volume technique 98
Convenience 117, 118, 152
Conversation 124
Convert thermal 113
Critical temperature 6
Crystalline 64, 101
Curriculum 13
Curvature 55, 114, 115, 144
Curvature radius 114, 115
Cylinders 7, 8, 21, 136, 145, 148, 149, 168, 169, 172, 173, 174

D

Deformation 3, 30, 37, 96, 97, 98, 101, 102, 103, 104
Demonstration 85
Density 2, 30, 41, 43, 44, 52, 54, 56, 62, 63, 65, 66, 67, 69, 70, 72, 82, 89, 90, 91, 100, 115, 120, 127, 140, 181, 188, 195, 197, 199
Disturbance intensity 74
Drag force 48, 133, 136, 137, 138, 139, 140, 141,

142, 143, 146, 149, 150, 153, 157, 158, 159, 160, 170
drawback 194

E

Elastic region 4
Electrical 41, 47, 64, 75, 78, 89, 125, 137
Electrically measure 137
Electricity 137, 181, 188
Electric motor 185
Electrolysis process 111
Electromagnetic 47
Electronic hardware cooling 8
Element 13, 25, 26, 43, 46, 54, 101, 103, 119, 161
Elliptical cylinder 146
Empirical data 193
Energy 6, 13, 18, 21, 22, 31, 41, 47, 49, 51, 53, 56, 57, 107, 108, 109, 110, 111, 113, 115, 118, 119, 121, 122, 123, 124, 125, 127, 128, 130, 131, 132, 166, 170, 178, 179, 180, 181, 182, 188, 191, 193, 199
Energy transfer 110, 125, 130, 131
Engineering Equation Solver (EES) 28
Entities 57
Entrainment via spray 133
Entropy 14, 54
Equilibrium 44, 45, 56, 57, 62, 70, 71, 72, 73, 74, 107, 109, 169
Equivalent 3, 27, 45, 63, 70, 76, 124, 125, 182, 185, 186, 187
Eulerian fluid characterization 83
exhaustive qualities 42
Extensive computer system 86
External forces 1, 100

F

Field 1, 19, 20, 21, 26, 34, 35, 36, 47, 57, 78, 79, 83, 85, 87, 89, 90, 92, 95, 99, 100, 101, 102, 103, 134, 163, 168, 197, 198, 199
Final observation 123
Flat plate 139, 140, 144, 145, 146, 150, 151, 154, 155, 156, 157, 167, 171, 172, 174

- Flexible membrane 49
 - Flourishing prehistoric 10
 - Flow attribute 94, 95
 - Flow-induced vibrations 28
 - Flow resistance 63
 - Flow separation 10, 91, 144, 147, 148, 158, 159, 167, 169
 - Flow visualization 88, 89, 101, 102, 103, 104
 - Fluctuation 73, 146
 - Fluid adheres 15
 - Fluid dynamic 7, 14, 208
 - Fluid dynamic application 7
 - Fluid dynamics 1, 7, 33, 78, 81, 85, 88, 95, 96, 97, 171, 193, 194, 197, 198, 199, 200, 201, 202, 204, 205, 206, 207, 208, 209, 210
 - Fluid engineering 13
 - Fluid inertia 12
 - fluid kinematics 83, 103
 - Fluid layer 4, 9, 48, 63, 78, 154
 - Fluid machinery 11
 - Fluid mechanics 1, 2, 7, 8, 10, 13, 14, 15, 18, 30, 31, 32, 37, 52, 88, 91, 92, 94, 96, 98, 100, 107, 110, 118, 177, 200, 206
 - Fluid mechanics application 7, 88
 - Fluid Motion 18
 - Fluid movement 13, 17, 83, 85, 86, 136
 - Fluid packets travel 86
 - Fluid particle 87, 100, 101, 127
 - Fluids flow 1
 - Fluid's kinetic 107
 - Fluids possess viscosity 113
 - Fluid statics 1, 67, 77
 - Force balance 68, 70, 119
 - Forge metals 11
 - Frequently employ 59
 - Friction 4, 13, 47, 48, 77, 100, 107, 113, 114, 119, 121, 123, 125, 136, 137, 138, 139, 142, 143, 144, 145, 146, 147, 149, 154, 155, 157, 158, 159, 167, 168, 169, 172, 173, 174
 - Frictional force 15, 47
 - Frictional impacts 142, 155
 - Fuel efficacy 67
 - Fuel injection system 7, 49
 - Fuel system 7
- G**
- Gaseous dynamics 86
 - Gaseous state 6, 43
 - Gas fluid 67
 - Geometry 20, 36, 70, 99, 103, 119, 128, 131, 149, 156, 170, 202
 - Global variable 193
 - Gravity 47, 52, 71, 72, 75, 78, 80, 81, 100, 113, 114, 127, 199
 - Grayscale 94
 - Groundwater sources 8
- H**
- Hazardous 27
 - Heat exchange 47, 124, 125, 200
 - Heat transfer 10, 28, 37, 113, 124, 125, 170, 173, 194
 - Heat transmission 14, 199
 - Homogeneity 2, 31, 33, 37, 38
 - Homogeneous 16, 135
 - Homogenous 24, 43
 - Horizontal distance 92
 - Horizontal plane 3, 47, 68, 69
 - Human body 7, 100
 - Humanity 10
 - Humidity 45
 - Hydraulic grade line 121, 122, 123
 - Hydraulic pump 113
 - Hydraulics 1, 37
 - Hydraulic system 67
 - Hydrodynamics 1, 57
 - Hydrogen 89, 92, 111
 - Hydrogen bubbles 89
 - Hydrology 2
 - Hydrostatic forces 57
 - Hydrostatics 67
 - Hypotheses 25, 26, 197
- I**
- Influence 5, 8, 75, 100, 127, 152, 175, 196, 203
 - Infrastructure 25

214 Fluid Mechanics

Inner flow resistance 15

Innovation 11

Insignificant 114, 119, 143, 155

Instance 4, 5, 6, 16, 17, 18, 20, 21, 22, 23, 25, 26, 44, 45, 47, 49, 59, 61, 63, 66, 71, 76, 85, 87, 88, 90, 94, 111, 112, 122, 123, 124, 125, 133, 135, 138, 139, 141, 144, 147, 148, 150, 151, 153, 157, 161, 180, 193, 201, 203, 204, 205

Interior power 47

Intermolecular 5, 130

Internal combustion engines 18

Interrelation 25

Inventor 64

Investigation 17, 82, 139, 168

K

Kinematic 83, 100, 104, 105, 195

Kinetic charges 113

L

Linear acceleration 57, 58

Linear momentum 110, 195

Liquid drop 133

Liquid pumps 123

Liquids 1, 2, 5, 12, 15, 17, 30, 36, 39, 45, 47, 52, 53, 58, 74, 76, 120, 121, 206

Liquid state 5

Liquid velocity 8, 112

Liquid vessel 4

Local atmospheric pressure 60

Logical system 22

Lubricating system 8

M

Magnetic 47, 75

Magnitude 22, 48, 69, 92, 93, 94, 198

Manometer 57, 62, 63, 78, 79, 81, 117

Mass change 109, 111

Mass interaction 22

Mass relationship 109

Material 3, 6, 21, 23, 30, 37, 43, 44, 45, 52, 76, 83, 84, 89, 97, 104

Material transform 44, 52

Matrix 194, 196, 199

Measure units 23

Mechanical power 107, 113, 122, 125

Mechanics 1

Mechanism 21, 22, 90, 124, 125, 174

Metacentric 73, 74

Meteorology 2

Methodology 25

Metric Agreement 23

Metric measurements 24

Microscopic perspective 49, 86

Minuscule 15, 114

Moisture 45

Molar mass 44

Molecular scale 43, 55

Molecular structure 47

Molecule 4

Momentum 13, 31, 85, 109, 110, 113, 114, 124, 128, 129, 131, 132, 157, 159, 200

Momentum energy 85

Motion 1, 2, 6, 8, 12, 13, 15, 17, 31, 36, 47, 48, 57, 58, 72, 74, 77, 78, 80, 81, 82, 85, 86, 88, 96, 97, 98, 100, 102, 104, 107, 109, 114, 125, 127, 132, 133, 137, 141, 157, 167, 195, 199, 200, 207, 208, 209

Motivation 139

Movement 1, 2, 7, 8, 16, 17, 18, 21, 30, 47, 55, 74, 83, 88, 96, 100, 114, 124, 126, 141, 163, 195, 200

Muscular 11

N

Natural convection 91, 105, 171

Natural gas 7, 8

Natural laws 110

Network 10, 25, 78, 123, 124, 171, 187

O

Occasionally 44

Oceanography 2

Optical image 90

Optimistic model 26

Optimization 145, 168, 170, 189

Orthogonal 134, 135
 Oscillation 19, 129, 147
 Oxygen 43, 44, 66, 111

P

Parametric 193
 Pascal combined 12
 Perpendicular force 48
 Petroleum products 8
 Phenomenon 4, 25, 46, 49, 50, 115, 147, 148, 150, 160, 163, 166
 Photography 86
 Physical phenomena 133, 136
 Physical process 8, 25, 27
 Piezoelectric 64
 Piezoelectric sensors 64
 Piezometric tubes 117
 Piston-cylinder mechanism 21
 Plasma 3, 49
 Plate-rubber interface 4
 Polymer 5
 Potential 28, 46, 56, 57, 64, 107, 113, 115, 121, 124, 162, 163, 206
 Power transmission 126
 Precision 2, 29, 30, 79, 154, 199
 Pressure 3, 4, 6, 7, 12, 15, 18, 20, 31, 41, 42, 43, 44, 45, 46, 49, 52, 53, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 74, 75, 76, 77, 78, 79, 80, 81, 82, 87, 91, 92, 94, 95, 113, 114, 116, 117, 118, 121, 122, 123, 127, 128, 129, 130, 132, 136, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 149, 153, 155, 157, 158, 159, 160, 162, 163, 165, 167, 169, 170, 178, 179, 180, 182, 184, 185, 186, 188, 190, 193, 195, 198, 199, 200, 208, 209
 Proportionality 109
 Pump performance 181, 183, 184, 185

Q

Quantitative approach 88
 Quantitative information 88
 Quantity 6, 11, 21, 22, 25, 49, 92, 97, 109, 112,

119, 124, 125, 204
 Quiescent fluid 133, 161

R

Rainfall cycle 8
 Rapid layer 15
 Realistic fluid system 6
 Realistic version 26
 Rectangular 74, 93, 150, 151, 166, 200, 201, 203, 204
 Refraction quality 89
 Refrigeration travels 7
 Refrigerator 7
 Regular monitoring 85
 Relative velocity 112
 Respiratory apparatuses 7
 Reynolds transport theorem (RTT) 83, 99
 Rotating vessels 57
 Rotation 96, 97, 126

S

Satellite dish 154
 Scalar inflow 86
 Scalar parameter 92
 Sensor function 64
 Software product 27
 Solar panels 17
 Solid 1, 3, 5, 6, 7, 8, 9, 10, 15, 16, 26, 30, 46, 47, 50, 52, 55, 57, 64, 67, 68, 70, 74, 77, 80, 91, 96, 97, 98, 102, 119, 123, 133, 147
 Solid surfaces 1, 8, 15, 16, 30, 91, 119
 Solid transform 6
 solitary substances 124
 Sophisticated instruments 111
 Spray inflate 98
 Spraying process 98
 Steady-flow operation 112
 Streamlining affects 145
 Sufficiently large 74, 148
 Supersonic 7, 89, 91, 130, 175
 Surface 3, 4, 5, 8, 9, 10, 15, 16, 17, 21, 30, 31, 32, 39, 42, 46, 47, 48, 49, 50, 51, 54, 55, 57, 62,

216 Fluid Mechanics

63, 65, 66, 67, 68, 69, 70, 74, 75, 76, 78, 79, 80,
81, 91, 98, 100, 103, 104, 105, 112, 118, 119, 122,
123, 134, 136, 138, 141, 143, 145, 146, 147, 148,
152, 154, 155, 156, 157, 158, 159, 160, 162, 163,
165, 168, 169, 170, 172, 173, 174, 184, 194, 195,
196, 197
Surface tension 31, 42, 47, 49, 50, 51, 54, 55, 62,
75, 78, 79, 100
Sustainability 57
Symmetric 138, 171
Syracuse 11

T

Tangential shear pressures 138
Temperature 10, 22, 23, 39, 41, 44, 45, 52, 66,
77, 82, 89, 91, 92, 113, 120, 124, 125, 128, 130,
156, 184, 185, 188, 197, 199
Tensile force 4
Thermal energy 124
Thermodynamics 28, 36, 52, 85, 113, 116, 123
Transformation 83, 105, 107
Translation 96, 97
Traveling alongside 112, 133
Turbine 14, 22, 109, 113, 119, 122, 128, 129,
154, 178, 179, 180, 181, 188, 209
Turbomachine 177, 180
Turbomachinery efficiency 148
Turbulence 194, 200, 209
Turbulent boundary layers 82, 114, 169

U

Unit length 49

V

Vacuum 7, 12, 43
Vacuum pressure 60, 61

Vapor 6, 42
Vector 35, 68, 83, 85, 87, 91, 92, 93, 94, 96, 102,
103, 104, 112, 178, 195
Velocity 1, 4, 8, 9, 10, 13, 17, 20, 21, 22, 30, 34,
47, 67, 85, 87, 88, 89, 91, 92, 93, 94, 96, 97, 100,
112, 113, 114, 115, 116, 121, 122, 125, 134, 135,
140, 141, 142, 144, 146, 147, 148, 150, 153, 154,
155, 156, 157, 159, 160, 161, 162, 163, 165, 167,
171, 179, 183, 185, 193, 195, 198, 200
Vertical plane surface 68
Vertical transparency 117
Vessel 5, 6, 58, 180
Vibrating structure 9
Viscosity 9, 16, 31, 42, 47, 52, 53, 54, 143, 167
Visibility 115
Visual analysis 88
Volume 4, 18, 21, 22, 23, 30, 34, 35, 37, 41, 43,
44, 50, 52, 66, 68, 70, 72, 73, 75, 83, 86, 87, 97,
98, 99, 109, 110, 111, 112, 127, 148, 152, 179,
180, 181, 183, 184, 185, 186, 194, 196, 207, 209
Vortex movement 14

W

Waves 8, 14, 19, 20, 45, 52, 55, 56, 80, 82, 89,
90, 138
Wind generator 8
work transmission 125

Z

Zero acceleration 8, 142
Zero mass 21
Zero viscosity 15

