Table of contents

- Preface (p. xiii)
- **Glossary** (p. xvii)
- I Elements of Continuum Mechanics (p. 1)
- 1.1 Biological Transport Processes (p. 2)
- 1.1.1 Micro-to Macro-scale Systems (p. 2)
- 1.1.2 Solute Transport (p. 7)
- 1.2 Basic Momentum, Heat, and Mass Transfer Concepts (p. 13)
- 1.2.1 Continuum Mechanics Axioms (p. 18)
- 1.2.2 Flow Field Descriptions (p. 19)
- 1.2.2.1 Lagrangian Description (p. 20)
- **1.2.2.2 Eulerian Description** (p. 21)
- 1.2.3 Derivation Approaches (p. 22)
- 1.3 Conservation Laws (p. 24)
- **1.3.1 Mass Conservation** (p. 26)
- 1.3.2 Momentum Conservation (Integral Approach) (p. 27)
- 1.3.2.1 Stress Tensors and Stress Vectors (p. 30)
- 1.3.2.2 Equation of Motion and its Special Cases (p. 34)
- 1.3.2.3 Force Balance Derivation (p. 36)
- **1.3.3 Energy Conservation** (p. 42)
- 1.3.3.1 Heat and Mass Transfer Equations (p. 43)
- 1.3.3.2 Basic Heat and Mass Transfer Applications (p. 44)
- 1.3.4 Turbulent Flow Equations (p. 49)
- **1.3.4.1 Aspects of Turbulence** (p. 49)
- **1.3.4.2 Turbulence Scales** (p. 54)
- 1.3.4.3 Summary of Turbulence Modeling (p. 55)
- 1.3.5 Solution Techniques (p. 64)
- 1.3.5.1 Solution Methods for Differential Equations (p. 67)
- 1.3.5.2 Solution Procedures for the Navier-Stokes Equations (p. 67)
- **1.3.5.3 Similarity Theory** (p. 71)
- **1.3.5.4 Integral Methods** (p. 72)
- 1.3.5.5 Dimensional Analysis and Scaling (p. 76)
- **1.4 Two-Phase Flows** (p. 78)
- 1.4.1 Modeling Approaches (p. 79)
- **1.4.1.1 Definitions** (p. 81)
- 1.4.1.2 Phase Coupling (p. 83)
- **1.4.2 Mixture Models** (p. 88)
- 1.4.2.1 Homogeneous and Non-Newtonian Flow Models (p. 88)
- **1.4.2.2 Drift-Flux Model** (p. 98)
- 1.4.3 Separated Flow Models (p. 99)
- 1.4.3.1 Particle Trajectory Models (p. 99)
- **1.4.3.2 Species Mass Transfer** (p. 108)
- **1.4.4 Porous Media Flow** (p. 109)
- 1.5 Biomechanics Review (p. 120)

- 1.5.1 Introduction (p. 120)
- **1.5.2 Principal Stresses** (p. 120)
- 1.5.3 Equilibrium Conditions (p. 126)
- 1.5.4 Deformation Analysis and Stress-Strain Relationships (p. 127)
- **1.5.5 Simplifications** (p. 131)
- **1.6 Summary and Outlook** (p. 137)
- 1.7 Homework Assignments (p. 139)
- References (p. 155)
- II Biofluid Dynamics Concepts (p. 161)
- **2.1 Transport Phenomena** (p. 162)
- 2.1.1 Biofluid-compartment Models (p. 163)
- 2.1.2 Tissue Heat and Mass Transfer (p. 173)
- **2.1.3 Joint Lubrication** (p. 186)
- 2.1.4 Cell Transport and Microvascular Beds (p. 192)
- **2.2 The Cardiovascular System** (p. 197)
- **2.2.1 Cardiovascular Transport Dynamics** (p. 197)
- **2.2.2 The Heart** (p. 199)
- **2.2.3 The Blood Vessels** (p. 209)
- 2.3 Homework Problems (p. 232)
- References (p. 237)
- III Analyses of Arterial Diseases (p. 241)
- **3.1 Vessel Occlusions** (p. 241)
- 3.1.1 Atherosclerotic Plaque Formation (p. 242)
- 3.1.1.1 A Particle-Hemodynamics Model (p. 244)
- 3.1.1.2 A Pathway Model for Atherogenesis (p. 244)
- 3.1.2 Intimal Hyperplasia Development (p. 245)
- **3.1.3 Thrombogenesis** (p. 246)
- 3.1.4 Particle-Hemodynamics (p. 247)
- 3.1.4.1 Equations of Particle Motion (p. 251)
- **3.1.4.2 Near-Wall Forces** (p. 254)
- 3.1.4.3 Hemodynamic Wall Parameters (p. 257)
- 3.1.5 Treatment Option: Femoral End-to-Side Graft Bypass (p. 265)
- 3.1.5.1 Computational Fluid-Particle Dynamics Solution (p. 266)
- **3.1.5.2 Model Validation** (p. 271)
- 3.1.5.3 Results for a Distal End-to-Side Femoral Bypass (p. 272)
- 3.1.5.4 Novel System Design and Discussion (p. 276)
- **3.2 Aneurysms** (p. 278)
- **3.2.1 Aortic Aneurysms** (p. 279)
- 3.2.1.1 Mechanisms of AAA Development (p. 280)
- **3.2.1.2 AAA-Wall Stress and Rupture** (p. 282)
- 3.2.2 Treatment Option: Stent-graft Implants (p. 283)
- 3.2.3 Stented AAA-model Analysis (p. 284)
- 3.2.3.1 Basic Structure Equations (p. 287)
- **3.2.3.2 Numerical Method** (p. 287)
- **3.2.3.3 Model Validations** (p. 289)
- **3.2.3.4 Results and Discussion** (p. 290)

- **3.2.3.5 Conclusions** (p. 295)
- 3.3 Examples of Computerized Disease Management (p. 296)
- **3.3.1 Introduction** (p. 296)
- 3.3.2 Image File Conversion Steps (p. 297)
- 3.3.3 A Stenosed Artery Model for Surgical Bypass Planning (p. 303)
- **3.3.4 AAA-Rupture Prediction** (p. 306)
- 3.4 Homework Problems (p. 311)
- **References** (p. 313)
- IV Biofluid Mechanics of Organ Systems (p. 321)
- **4.1 The Lungs** (p. 322)
- **4.1.1 Respiratory Tract Geometry** (p. 328)
- 4.1.2 Pulmonary Disorders and Treatment Options (p. 330)
- **4.2 The Kidneys** (p. 339)
- **4.2.1 Kidney Structure and Functions** (p. 340)
- 4.2.2 Fluid Flow and Mass Transfer in an Artificial Kidney Model (p. 342)
- **4.3 The Liver** (p. 349)
- 4.3.1 Liver Structure and Functions (p. 351)
- 4.3.2 Fluid Flow and Mass Transfer in a Liver Model (p. 351)
- **4.4 Homework Problems** (p. 358)
- **References** (p. 361)
- V Case Studies in Biofluid Dynamics (p. 363)
- 5.1 Prerequisites for Modeling and Simulating (p. 364)
- 5.1.1 Problem Recognition and System Conceptualization (p. 366)
- 5.1.2 Types of Models and Modeling Approaches (p. 367)
- 5.1.3 Mathematical Representation and System Simulation (p. 371)
- **5.2 Nanodrug Delivery in Microchannels** (p. 376)
- **5.2.1 Flow in Microchannels** (p. 377)
- **5.2.1.1 Numerical Solution Techniques** (p. 378)
- **5.2.1.2 Microchannel Flow Effects** (p. 383)
- 5.2.2 Controlled Nanodrug Delivery in Microchannels (p. 392)
- 5.3 Particle Deposition and Targeting in Human Lung Airways (p. 397)
- 5.3.1 Nanoparticle and Microparticle Depositions in a Human Upper Airway Model (p. 399)
- **5.3.2 Modeling Approach and Results** (p. 399)
- **5.3.2.1 Numerical Method** (p. 404)
- **5.3.2.2 Model Validations** (p. 405)
- **5.3.2.3 Results and Discussion** (p. 407)
- **5.3.2.4 Conclusions** (p. 418)
- 5.3.3 Micro-drug Aerosol Targeting in Lung Airways (p. 419)
- 5.4 Fluid-Structure Interactions in Stented Aneurysms (p. 422)
- 5.4.1 Aneurysms and Their Possible Repairs (p. 422)
- 5.4.2 A Stented Abdominal Aortic Aneurysm Model (p. 426)
- **5.4.2.1 Introduction** (p. 426)
- **5.5 Project Assignments** (p. 443)
- **5.4.2.2 Theory** (p. 428)
- **5.4.2.3 Results** (p. 434)

- **5.4.2.4 Discussion** (p. 441)
- **References** (p. 445)
- **Appendices** (p. 451)
- A Review of Tensor Calculus, Differential Operations, Integral Transformations, and ODE Solutions (p. 452)
- **B Single-Phase Field Equations** (p. 468)
- C Suitable CFD Solvers (p. 470)
- D Physical Properties (p. 475)
- **References** (p. 478)
- **Index** (p. 479)