Table of Contents


- Preface p. xv
- About The author p. xix
- Chapter 1 Overview p. 1
- 1.1 Introduction p. 1
- 1.2 Synopses of Topics Covered in Various Chapters p. 3
- 2.1 Introduction p. 7
- 2.2.2 Equation of Permeability p. 13
- 2.2.3 Derivation of the Equation of Permeability p. 16
- 2.2.5 Data Analysis and Correlation Method p. 24
- 2.2.6 Parametric Relationships of Typical Data p. 26
- 2.2.6.1 Example 1: Synthetic Spheres p. 26
- 2.2.6.2 Example 2: Dolomite p. 26
- 2.2.6.3 Example 3: Berea Sandstone 27
- 2.2.7.1 Example 4: Synthetic Porous Media p. 29
- 2.2.7.3 Example 6: Silty Soil p. 33
- 2.3.1 Permeability Alteration by Scale Deposition p. 36
- Chapter 2 Transport Properties Of Porous Media p. 7
- 2.2.7 Correlation of Typical Permeability Data p. 29
- 2.3 Permeability of Porous Media Undergoing Alteration by Scale Deposition p. 33
- 2.2 Permeability of Porous Media Based on the Bundle of Tortuous Leaky-Tube Model p. 10
- 2.2.4 Pore Connectivity and Parametric Functions p. 20
- 2.2.7.2 Example 5: Glass Bead and Sand Packs p. 31
- 2.2.1 Pore Structure p. 11
- 2.3.2 Permeability Alteration in Thin Porous Disk by Scale Deposition p. 37
- 2.3.3 Data Analysis and Correlation Method p. 38
- 2.3.4 Correlation of Scale Effect on Permeability p. 39
- 2.3.4.1 Example 7: Scale Formation p. 39
- 2.3.4.2 Example 8: Acid Dissolution p. 40
- 2.3.4.3 Example 9: Wormhole Development p. 42
- 2.4 Temperature Effect on Permeability p. 44
- 2.4.1 The Modified Kozeny-Carman Equation p. 46
- 2.4.2 The Vogel-Tammann-Fulcher (VTF) Equation p. 49
- 2.4.3 Data Analysis and Correlation p. 51
- 2.4.3.1 Example 10: Correlation Using the Modified Kozeny-Carman Equation p. 51
- 2.4.3.2 Example 11: Correlation Using the VTF Equation p. 52
- 2.5 Effects of Other Factors on Permeability p. 54
- 2.6 Exercises p. 54
- Chapter 3 Macroscopic Transport Equations p. 57
- 3.1 Introduction p. 57
- 3.2 Rev p. 58
- 3.3 Volume-Averaging Rules p. 59
- 3.4 Mass-Weighted Volume-Averaging Rule p. 61
- 3.5 Surface Area Averaging Rules p. 68

- 3.6 Applications of Volume and Surface Averaging Rules p. 68
- 3.7 Double Decomposition for Turbulent Processes in Porous Media p. 70
- 3.8 Tortuosity Effect p. 73
- 3.9 Macroscopic Transport Equations by Control Volume Analysis p. 74
- 3.10 Generalized Volume-Averaged Transport Equations p. 76
- 3.11 Exercises p. 76
- Chapter 4 Scaling And Correlation Of Transport In Porous Media p. 79
- 4.1 Introduction p. 79
- 4.2 Dimensional and Inspectional Analysis Methods p. 81
- 4.2.1 Dimensional Analysis p. 81
- 4.2.2 Inspectional Analysis p. 82
- 4.3 Scaling p. 84
- 4.3.1 Scaling as a Tool for Convenient Representation p. 84
- 4.3.2 Scaling as a Tool for Minimum Parametric Representation p. 84
- 4.3.3 Normalized Variables p. 86
- 4.3.4 Scaling Criteria and Options for Porous Media Processes p. 87
- 4.3.5 Scaling Immiscible Fluid Displacement in Laboratory Core Floods p. 89
- 4.4 Exercises p. 92
- Chapter 5 Fluid Motion In Porous Media p. 97
- 5.1 Introduction p. 97
- 5.2 Flow Potential p. 98
- 5.3 Modification of Darcy's Law for Bulk- versus Fluid Volume Average Pressures p. 99
- 5.4 Macroscopic Equation of Motion from the Control Volume Approach and Dimensional Analysis p. 102
- 5.5 Modification of Darcy's Law for the Threshold Pressure Gradient p. 105
- 5.6 Convenient Formulations of the Forchheimer Equation p. 108
- 5.7 Determination of; the Parameters of the Forchheimer Equation p. 111
- 5.8 Flow Demarcation Criteria p. 115
- 5.9 Entropy Generation in Porous Media p. 117
- 5.9.1 Flow through a Hydraulic Tube p. 118
- 5.9.2 Flow through Porous Media p. 120
- 5.10 Viscous Dissipation in Porous Media p. 123
- 5.11 Generalized Darcy's Law by Control Volume Analysis p. 124
- 5.11.1 General Formulation p. 126
- 5.11.2 Simplified Equations of Motion for Porous Media Flow p. 132
- 5.12 Equation of Motion for Non-Newtonian Fluids p. 134
- 5.12.1 Frictional Drag for Non-Newtonian Fluids p. 134
- 5.12.2 Modified Darcy's Law for Non-Newtonian Fluids p. 135
- 5.12.3|yModified Forchheimer Equation for Non-Newtonian Fluids p. 137
- 5.13 Exercises p. 138
- Chapter 6 Gas Transport In Tight Porous Media p. 145
- 6.1 Introduction p. 145
- 6.2 Gas Flow through a Capillary Hydraulic Tube p. 146
- 6.3 Relationship between Transports Expressed on Different Bases p. 147
- 6.4 The Mean Free Path of Molecules: FHS versus VHS p. 149

- 6.5 The Knudsen Number p. 150
- 6.6 Flow Regimes and Gas Transport at Isothermal Conditions p. 152
- 6.6.1 Knudsen Regime p. 154
- 6.6.2 Slip/Transition Regime p. 156
- 6.6.3 Viscous Regime p. 157
- 6.6.4 Adsorbed-Phase Diffusion p. 158
- 6.6.5 Liquid Viscous or Capillary Condensate Flow p. 159
- 6.7 Gas Transport at Nonisothermal Conditions p. 159
- 6.8 Unified Hagen-Poiseuille-Type Equation for Apparent Gas Permeability p. 160
- 6.8.1 The Rarefaction Coefficient Correlation p. 161
- 6.8.2 The Apparent Gas Permeability Equation p. 162
- 6.8.3 The Klinkenberg Gas Slippage Factor Correlation p. 163
- 6.9 Single-Component Gas Flow p. 165
- 6.10 Multicomponent Gas Flow p. 166
- 6.11 Effect of Different Flow Regimes in a Capillary Flow Path and the Extended Klinkenberg Equation p. 168
- 6.12 Effect of Pore Size Distribution on Gas Flow through Porous Media p. 170
- 6.13 Exercises p. 174
- Chapter 7 Fluid Transport Through Porous Media p. 177
- 7.1 Introduction p. 177
- 7.2 Coupling Single-Phase Mass and Momentum Balance Equations p. 178
- 7.3 Cylindrical Leaky-Tank Reservoir Model Including the Non-Darcy Effect p. 179
- 7.4 Coupling Two-Phase Mass and Momentum Balance Equations for Immiscible Displacement p. 186
- 7.4.1 Macroscopic Equation of Continuity p. 186
- 7.4.2 Application to Oil/Water Systems p. 187
- 7.4.2.1 Pressure and Saturation Formulation p. 188
- 7.4.2.2 Saturation Formulation p. 189
- 7.4.2.3 Boundary Conditions p. 190
- 7.4.3 One-Dimensional Linear Displacement p. 190
- 7.4.4 Numerical Solution of Incompressible Two-Phase Fluid Displacement Including the Capillary Pressure Effect p. 191
- 7.4.5 Fractional Flow Formulation p. 192
- 7.4.6 The Buckley-Leverett Analytic Solution Neglecting the Capillary Pressure Effect p. 193
- 7.4.7 Convenient Formulation p. 194
- 7.4.8 Unit End-Point Mobility Ratio Formulation p. 195
- 7.4.8.1 Example 1 p. 196
- 7.4.8.2 Example 2 p. 198
- 7.5 Potential Flow Problems in Porous Media p. 200
- 7.5.1 Principle of Superposition p. 200
- 7.5.2 Principle of Imaging p. 202
- 7.5.3 Basic Method of Images p. 202
- 7.5.4 Expanded Method of Images p. 205
- 7.6 Streamline/Stream Tube Formulation and Front Tracking p. 205
- 7.6.1 Basic Formulation p. 206

- 7.6.2 Finite Analytic Representation of Wells in Porous Media p. 211
- 7.6.3 Streamline Formulation of Immiscible Displacement in Uuconfined Reservoirs p. 213
- 7.6.4 Streamline Formulation of Immiscible Displacement Neglecting Capillary Pressure Effects in Confined Reservoirs p. 214
- 7.7 Exercises p. 218
- Chapter 8 Parameters Of Fluid Transfer In Porous Media p. 227
- 8.1 Introduction p. 227
- 8.2 Wettability and Wettability Index p. 230
- 8.3 Capillary Pressure p. 231
- 8.4 Work of Fluid Displacement p. 234
- 8.5 Temperature Effect on Wettability-Related Properties of Porous Media p. 235
- 8.6 Direct Methods for the Determination of Porous Media Flow Functions and Parameters p. 238
- 8.6.1 Direct Interpretation Methods for the Unsteady-State Core Tests p. 238
- 8.6.1.1 Basic Relationships p. 238
- 8.6.1.2 Solution Neglecting the Capillary End Effect for Constant Fluid Properties p. 242
- 8.6.1.3 Inferring Function and Function Derivative Values from Average Function Values p. 245
- 8.6.1.4 Relationships for Processing Experimental Data p. 247
- 8.6.1.5 Applications p. 251
- 8.6.2 The et al. Formulae for the Direct Determination of Relative Permeability from Unsteady-State Fluid Displacements p. 251
- 8.6.2.1 Determination of Relative Permeability under Variable Pressure and Rate Conditions p. 253
- 8.6.2.2 Determination of Relative Permeability under Constant Pressure Conditions p. 256
- 8.6.2.3 Determination of Relative Permeability under Constant Rate Conditions p. 257
- 8.6.2.4 Applications for Data Analysis p. 257
- 8.7 Indirect Methods for the Determination of Porous Media Flow Functions and Parameters p. 259
- 8.7.1 Indirect Method for Interpretation of the Steady-State Core Tests p. 260
- 8.7.2 Unsteady-State Core Test History Matching Method for the Unique and Simultaneous Determination of Relative Permeability and Capillary Pressure p. 261
- 8.7.2.1 Formulation of a Two-Phase Flow in Porous Media p. 261
- 8.7.2.2 Representation of Flow Functions p. 263
- 8.7.2.3 Parameter Estimation Using the Simulated Annealing Method p. 265
- 8.7.2.4 Applications for Drainage Tests p. 267
- 8.7.2.5 Applications for Imbibition Tests p. 269
- 8.8 Exercises p. 276
- Chapter 9 Mass, Momentum, And Energy Transport In Porous Media p. 281
- 9.1 Introduction p. 281
- 9.2 Dispersive Transport of Species in Heterogeneous and Anisotropic Porous Media p. 282
- 9.2.1 Molecular Diffusion p. 283

- 9.2.2 Hydrodynamic Dispersion p. 283
- 9.2.3 Advective/Convective Flux of Species p. 285
- 9.2.4 Correlation of Dispersivity and Dispersion p. 286
- 9.3 General Multiphase Fully Compositional Nonisothermal Mixture Model p. 288
- 9.4 Formulation of Source/Sink Terms in Conservation Equations p. 292
- 9.5 Isothermal Black Oil Model of a Nonvolatile Oil System p. 295
- 9.6 Isothermal Limited Compositional Model of a Volatile Oil System p. 298
- 9.7 Flow of Gas and Vaporizing Water Phases in the Near-Wellbore Region p. 299
- 9.8 Flow of Condensate and Gas Phase Containing Noncondensable Gas Species in the Near-Wellbore Region p. 301
- 9.9 Shape-Averaged Formulations p. 305
- 9.9.1 Thickness-Averaged Formulation p. 305
- 9.9.2 Cross-Sectional Area-Averaged Formulation p. 306
- 9.10 Conductive Heat Transfer with Phase Change p. 307
- 9.10.1 Unfrozen Water in Freezing and Thawing Soils: Kinetics and Correlation p. 309
- 9.10.2 Kinetics of Freezing/Thawing Phase Change and Correlation Method p. 311
- 9.10.3 Representation of the Unfrozen Water Content for Instantaneous Phase Change p. 317
- 9.10.4 Apparent Heat Capacity Formulation for Heat Transfer with Phase Change p. 318
- 9.10.5 Enthalpy Formulation of Conduction Heat Transfer with Phase Change at a Fixed Temperature p. 322
- 9.10.6 Thermal Regimes for Freezing and Thawing of Moist Soils: Gradual versus Fixed Temperature Phase Change p. 326
- 9.11 Simultaneous Phase Transition and Transport in Porous Media Containing Gas Hydrates p. 328
- 9.12 Modeling Nonisothermal Hydrocarbon Fluid Flow Considering Expansion/Compression and Joule-Thomson Effects p. 338
- 9.12.1 Model Considerations and Assumptions p. 339
- 9.12.2 Temperature and Pressure Dependency of Properties p. 339
- 9.12.3 Mixture Properties p. 341
- 9.12.4 Equations of Conservations p. 342
- 9.12.5 Applications p. 345
- 9.13 Exercises p. 346
- Chapter 10 Suspended Particulate Transport In Porous Media p. 353
- 10.1 Introduction p. 353
- 10.2 Deep-Bed Filtration under Nonisothermal Conditions p. 355
- 10.2.1 Concentration of Fine Particles Migrating within the Carrier Fluid p. 356
- 10.2.2 Concentration of Fine Particles Deposited inside the Pores of the Porous Matrix p. 359
- 10.2.3 Variation of Temperature in the System of Porous Matrix and Flowing Fluid p. 359
- 10.2.4 Initial Filter Coefficient p. 361
- 10.2.5 Filter Coefficient Dependence on Particle Retention Mechanisms and Temperature Variation p. 363
- 10.2.6 Permeability Alteration by Particle Retention and Thermal Deformation p. 365
- 10.2.7 Applications p. 366

- 10.3 Cake Filtration over an Effective Filter p. 370
- 10.4 Exercises p. 379
- Chapter 11 Transport In Heterogeneous Porous Media p. 383
- 11.1 Introduction p. 383
- 11.2 Transport Units and Transport in Heterogeneous Porous Media p. 385
- 11.2.1 Transport Units p. 385
- 11.2.2 Sugar Cube Model of Naturally Fractured Porous Media p. 386
- 11.3 Models for Transport in Fissured/Fractured Porous Media p. 388
- 11.3.1 Analytical Matrix-Fracture Interchange Transfer Functions p. 388
- 11.3.2 Pseudo-Steady-State Condition and Constant Fracture Fluid Pressure over the Matrix Block: The Warren-Root Lump-Parameter Model p. 390
- 11.3.3 Transient-State Condition and Constant Fracture Fluid Pressure over the Matrix Block p. 391
- 11.3.4 Single-Phase Transient Pressure Model of de Swaan for Naturally Fractured Reservoirs p. 392
- 11.4 Species Transport in Fractured Porous Media p. 394
- 11.5 Immiscible Displacement in Naturally Fractured Porous Media p. 396
- 11.5.1 Correlation of the Matrix to-Fracture Oil Transfer p. 397
- 11.5.2 Formulation of the Fracture Flow Equation p. 402
- 11.5.3 Exact Analytical Solution Using the Unit End-Point Mobility Approximation p. 404
- 11.5.4 Asymptotic Analytical Solutions Using the Unit End-Point Mobility Approximation p. 405
- 11.5.4.1 Formulation p. 406
- 11.5.4.2 Small-Time Approximation p. 407
- 11.5.4.3 Approximation for Large Time p. 408
- 11.6 Method of Weighted Sum (Quadrature) Numerical Solutions p. 410
- 11.6.1 Formulation p. 411
- 11.6.2 Quadrature Solution p. 413
- 11.7 Finite Difference Numerical Solution p. 415
- 11.7.1 Formulation p. 416
- 11.7.2 Numerical Solutions p. 418
- 11.8 Exercises p. 425
- References p. 429
- Index p. 455