# CONTENTS

Preface ix
Contributors xi

**1 Bounded Higher-Order Upwind Multidimensional Finite-Volume Convection-Diffusion Algorithms**
*B. P. Leonard*
1 Introduction 1
2 Finite-Volume Formulation 8
3 Steady Multidimensional Flow 21
4 Explicit Update for Unsteady Flow 38
5 Research Frontiers 51
6 Conclusion 53
7 References 54

**2 Advances in Computation of Heat Transfer, Fluid Flow, and Solid Body Deformation Using Finite Volume Approaches**
*I. Demirdžić, S. Muzaferija and M. Perić*
1 Introduction 59
2 Mathematical Formulation 62
3 Finite-Volume Method 69
4 Applications of the Method 85
5 Conclusion 92
6 References 93

**3 Control-Volume Finite Element Methods for Fluid Flow and Heat Transfer**
*B. R. Baliga*
1 Introduction 97
2 Synopsis of Some CVFEMs and Related Methods for Fluid Flow and Heat Transfer 98
3 A CVFEM for Multidimensional, Steady, Incompressible Fluid Flow and Heat Transfer 107
4 Conclusion 126
5 Acknowledgments 128
6 References 128

**4 General Algorithms for the Finite Element Solution of Incompressible Flow Problems Using Primitive Variables**
*G. Comini, W. J. Minkowycz and W. Shyy*

1 Introduction 137
2 Statement of the Problem 139
3 Weak Forms of the Momentum Equations 140
4 The Continuity Equation 145
5 Finite Element Formulation 147
6 Coupled Solutions 152
7 Fully Decoupled Solutions 154
8 Equal Order Implementations 162
9 Conclusion 165
10 Nomenclature 166
11 References 167

**5 Two-Equation and Second-Moment Turbulence Models for Convective Heat Transfer**
*S. Ramadhyani*

1 Introduction 171
2 The Standard $k$-$\varepsilon$ Turbulence Model with Wall Functions 172
3 Low-Reynolds-Number $k$-$\varepsilon$ Models 177
4 Other Improvement to $k$-$\varepsilon$ Models 179
5 Other Two-Equation Models 183
6 The Turbulent Prandtl Number 185
7 Reynolds Stress/Flux Models 186
8 Algebraic Stress Models and Anisotropic $k$-$\varepsilon$ Models 190
9 Conclusion 192
10 References 193

**6 Multi-Resolution Computations for Fluid Flow and Heat/Mass Transfer**
*W. Shyy, J. Liu and H. Ouyang*

1 Introduction 201
2 Numerical Methods for Transport Equations 203
3 Scale Patching: Modeling Concepts 208
4 Resolution Patching: Multi-Block Grid 221
5 Conclusion 234
6 References 234

**7 Multigrid Methods for Internal Flows and Heat Transfer**
*S. P. Vanka and G. Wang*

1 Introduction 241
2 Governing Equations for Internal Flows 246
3 Details of Multigrid Procedures 247
4 Applications and Experiences 255
5 Conclusion 279
6 References 280

**8 An Overview of Recent Advances and Computational Methods for Thermal Problems**
*K. K. Tamma*

1 Introduction 287
2 Influence of Non-Classical/Classical Effects 288
3 Numerical Discretization 295
4 A Brief Overview of Computational Methods 298
5 A Generalized $\gamma_T$ - Family of Flux-Based Element Representations 312
6 Virtual-Pulse (VIP) Time Integral Methodology 319
7 Hybrid Transfinite Element Methodology 325
8 Closure: Thermal Problems Influenced by Non-Classical/Classical Effects 334
9 Acknowledgments 334
10 References 335

**9 An Overview of Numerical Methods for Solving Phase Change Problems**
*V. R. Voller*

1 Introduction 341
2 Numerical Discretization Schemes 342
3 The Stefan Problem 344
4 Fixed Grid Schemes 345
5 Deforming Grid Solutions 359
6 Hybrid Solutions 366
7 Discontinuous Thermal Properties 367
8 Problems with Fluid Flow 369
9 General Phase Change Problems 371
10 Conclusion 374
11 References 375

**10 Inverse Shape and Boundary Condition Problems and Optimization in Heat Conduction**
*G. S. Dulikravich and T.J. Martin*

I Introduction 381
2 Theoretical Formulation 382
3 Steady Inverse Heat Conduction Problems 389
4 Inverse Detection of Heat Sources 408
5 Optimization 409
6 Inverse Shape Design 410
7 Inverse Unsteady Boundary Condition Problems 419
8 Recommendations for Future Research 421
9 References 422

Index 427