

1. Record Nr.	UNINA9910592981803321
Autore	Wu Lei
Titolo	Rarefied gas dynamics : kinetic modeling and multi-scale simulation / / Lei Wu
Pubbl/distr/stampa	Singapore : , : Springer, , [2022] ©2022
ISBN	9789811928727 9789811928710
Descrizione fisica	1 online resource (293 pages) : illustrations (black and white, and colour)
Disciplina	533.2
Soggetti	Rarefied gas dynamics - Mathematical models Rarefied gas dynamics
Lingua di pubblicazione	Inglese
Formato	Materiale a stampa
Livello bibliografico	Monografia
Note generali	Includes index.
Nota di contenuto	Intro -- Preface -- Contents -- 1 Introduction -- 1.1 Navier-Stokes- Fourier Equations -- 1.2 Continuum Breakdown -- 1.2.1 Reentry of Space Vehicle -- 1.2.2 Microelectromechanical Systems -- 1.2.3 Shale Gas Extraction -- 1.2.4 Global Wind Profiling -- 1.3 Simple Gas Kinetic Theory -- 1.4 Knudsen Number -- 1.4.1 Spatial Knudsen Number -- 1.4.2 Temporal Knudsen Number -- 1.5 Molecular Dynamics Simulations -- References -- 2 Gas Kinetic Theory -- 2.1 Velocity Distribution Function -- 2.2 Binary Collision -- 2.2.1 Deflection Angle -- 2.2.2 Differential Cross Section -- 2.2.3 Grazing Collision -- 2.3 Boltzmann Equation -- 2.3.1 H-Theorem -- 2.3.2 Equilibrium Collision Frequency -- 2.3.3 Linearized Boltzmann Equation -- 2.4 Wang-Chang and Uhlenbeck Equation -- 2.5 Enskog Equation -- 2.5.1 Liquid-Vapor Flow -- 2.5.2 Granular Gas -- 2.6 Gas-Surface Boundary Condition -- 2.6.1 Maxwell Boundary Condition -- 2.6.2 Epstein Boundary Condition -- 2.6.3 Cercignani-Lampis Boundary Condition -- 2.7 Numerical Methods -- 2.7.1 Direct Simulation Monte Carlo -- 2.7.2 Discrete Velocity Methods -- 2.7.3 Multi-scale Simulation -- References -- 3 Fluid-Dynamic Equation -- 3.1 Hilbert Expansion -- 3.2 Chapman- Enskog Expansion -- 3.2.1 Expansion in Sonine Polynomials -- 3.2.2 Expansion to the First Order -- 3.2.3 Expansion to Higher Orders --

3.3 Moment Methods -- 3.4 Accuracy of Macroscopic Equations --
3.4.1 Equations from Chapman-Enskog Expansion -- 3.4.2 Moment
Equations -- 3.5 Convergence of Moment Equations -- 3.5.1 Rayleigh-
Brillouin Scattering -- 3.5.2 Sound Propagation -- References -- 4 Fast
Spectral Method for Monatomic Gas Flow -- 4.1 Inverse Design of
Collision Kernel -- 4.1.1 Power-Law Potential -- 4.1.2 Lennard-Jones
Potential -- 4.2 Normalization -- 4.3 Fast Spectral Method -- 4.3.1
Carleman Representation -- 4.3.2 Fourier-Galerkin Spectral Method.
4.3.3 Detailed Implementation -- 4.3.4 Non-uniform Discretization of
Velocity Space -- 4.4 Homogeneous Relaxation -- 4.4.1 Bobylev-
Krook-Wu Solution -- 4.4.2 Discontinuous Velocity Distribution -- 4.5
Accuracy in Inhomogeneous Problems -- 4.5.1 Normal Shock Waves --
4.5.2 Force-Driven Poiseuille Flows -- 4.5.3 Thermal Transpiration in a
Cavity -- 4.6 Concluding Remarks -- References -- 5 Fast Spectral
Method for Linear Gas Flow -- 5.1 Linearization -- 5.2 Poiseuille Flow
-- 5.2.1 Poiseuille Flow Between Parallel Plates -- 5.2.2 Poiseuille Flow
Through a Long Duct -- 5.3 Thermal Transpiration -- 5.4 Onsager-
Casimir Relation -- 5.5 Influence of Intermolecular Potential -- 5.5.1
Lennard-Jones Potential -- 5.5.2 Accurate Transport Coefficients --
5.5.3 Poiseuille Flow -- 5.5.4 Planar Fourier Flow -- 5.5.5 Planar
Couette Flow -- 5.6 Cercignani-Lampis Boundary Condition -- 5.6.1
Poiseuille Flow Through Parallel Plates -- 5.6.2 Poiseuille Flow Through
Long Tube -- References -- 6 Kinetic Modeling of Monatomic Gas Flow
-- 6.1 Basic Rules -- 6.2 Velocity-Independent Collision Frequency --
6.2.1 BGK Model -- 6.2.2 Ellipsoidal-Statistical BGK Model -- 6.2.3
Shakhov Model -- 6.2.4 Gross-Jackson Model -- 6.2.5 Nonlinearization
-- 6.3 Velocity-Dependent Collision Frequency -- 6.4 Fokker-Planck
Model -- 6.5 Accuracy of Kinetic Models -- 6.5.1 Normal Shock Wave
-- 6.5.2 Thermal Transpiration -- References -- 7 Kinetic Modeling of
Molecular Gas Flow -- 7.1 Bulk Viscosity -- 7.2 Thermal Conductivity
-- 7.3 Thermal Relaxation Rates in DSMC -- 7.4 Kinetic Models --
7.4.1 Hanson-Morse Model -- 7.4.2 Rykov Model -- 7.4.3 ESBGK
Model -- 7.4.4 Wu Model -- 7.5 Accuracy of Kinetic Models -- 7.5.1
Normal Shock Wave -- 7.5.2 Couette Flow -- 7.5.3 Maxwell's Demon
-- 7.6 Uncertainty Quantification -- 7.6.1 Normal Shock Wave -- 7.6.2
Flow Driven by Maxwell's Demon.
7.6.3 Thermal Transpiration in Cavity -- 7.7 Conclusions and
Discussions -- References -- 8 General Synthetic Iterative Scheme --
8.1 Problems of CIS -- 8.1.1 Slow Convergence -- 8.1.2 False
Convergence -- 8.2 General Synthetic Iterative Scheme -- 8.2.1
Scheme-I GSIS -- 8.2.2 Scheme-II GSIS -- 8.3 Properties of GSIS --
8.3.1 Super Convergence -- 8.3.2 Asymptotic Preserving -- 8.4
Numerical Tests -- 8.4.1 Coherent Rayleigh-Brillouin Scattering --
8.4.2 Planar Fourier Flow -- 8.4.3 Couette Flow Between Eccentric
Cylinders -- 8.5 Concluding Remarks and Outlooks -- References -- 9
Acoustics in Rarefied Gas -- 9.1 Formulation of the Problem -- 9.2
Oscillatory Couette Flow -- 9.3 Oscillating Lid-Driven Cavity Flow --
9.3.1 Scaling Law for Anti-resonant Frequency -- 9.4 Planar Sound
Propagation -- 9.5 Sound Propagation in Cavity -- 9.5.1 Two Types of
Resonances -- 9.5.2 Sound Speed -- References -- 10 Slip and Jump
Coefficients -- 10.1 State of the Problem -- 10.2 Viscous Slip -- 10.2.1
Viscous Slip Coefficient -- 10.2.2 Knudsen Layer Function -- 10.3
Thermal Slip -- 10.3.1 Thermal Slip Coefficient -- 10.3.2 Knudsen
Layer Function -- 10.3.3 Molecular Gases -- 10.4 Temperature Jump
-- References -- 11 Accuracy of Kinetic Boundary Condition -- 11.1
Reynolds Lubrication Equation -- 11.2 Experiments and Upscaling --
11.3 Approximate Velocity Slip Coefficients -- 11.4 Comparison with
Experiment -- 11.4.1 Poiseuille Flow Through a Rectangular Duct --

11.4.2 Thermal Transpiration in a Rectangular Duct -- 11.4.3 Thermal Transpiration Through a Long Tube -- 11.5 Implication in Hypersonic Flows -- References -- 12 Porous Media Flow -- 12.1 Apparent Gas Permeability -- 12.2 Kinetic Formulation -- 12.3 Accuracy of Navier-Stokes Equations -- 12.4 Interpretation of Experiment -- 12.5 Asymptotic Behavior at Large Kn -- References -- 13 Gas Mixture. 13.1 Boltzmann Equation for Gas Mixture -- 13.2 Fast Spectral Method -- 13.2.1 Accuracy Analysis -- 13.2.2 Efficient Algorithm for Large Mass Ratio -- 13.3 Accuracy in Inhomogeneous Problems -- 13.4 Linearization and GSIS -- 13.5 McCormack Model -- References -- 14 Dense Gas Flow -- 14.1 Fast Spectral Method -- 14.2 Heated Granular Gas -- 14.3 Force-Driven Poiseuille Flow -- 14.3.1 Mass Flow Rate of Dense Gas -- 14.3.2 Influence of Restitution Coefficient -- 14.4 Heat Transfer -- 14.5 Kinetic Model for Dense Gas -- References -- 15 Fluctuation and Light Scattering -- 15.1 Rayleigh-Brillouin Scattering -- 15.1.1 Spontaneous RBS -- 15.1.2 Coherent RBS -- 15.2 Numerical Methods -- 15.2.1 Monatomic Gas -- 15.2.2 Molecular Gas -- 15.3 Accuracy of the Tenti Model -- 15.3.1 Temperature Retrieval Error -- 15.4 Extraction of Gas Property -- References -- Appendix A Special Functions -- Appendix B Relaxation Rates of Maxwellian Molecules -- Appendix C Numerical Quadratures -- C.1 Gauss-Legendre Quadrature -- C.2 Gauss-Hermite Quadrature -- Appendix D Implementation of Fast Spectral Method -- D.1 Algorithm 1: Zero-Padding -- D.2 Algorithm 2: No Zero-Padding -- D.3 Algorithm 3: Collision Frequency -- Appendix E MATLAB Code for Normal Shock Wave -- Appendix F MATLAB Code for Poiseuille Flow and Thermal Transpiration -- Index.

Sommario/riassunto

This book highlights a comprehensive description of the numerical methods in rarefied gas dynamics, which has strong applications ranging from space vehicle re-entry, micro-electromechanical systems, to shale gas extraction. The book consists of five major parts: The fast spectral method to solve the Boltzmann collision operator for dilute monatomic gas and the Enskog collision operator for dense granular gas; The general synthetic iterative scheme to solve the kinetic equations with the properties of fast convergence and asymptotic preserving; The kinetic modeling of monatomic and molecular gases, and the extraction of critical gas parameters from the experiment of Rayleigh-Brillouin scattering; The assessment of the fluid-dynamics equations derived from the Boltzmann equation and typical kinetic gas-surface boundary conditions; The applications of the fast spectral method and general synthetic iterative scheme to reveal the dynamics in some canonical rarefied gas flows. The book is suitable for postgraduates and researchers interested in rarefied gas dynamics and provides many numerical codes for them to begin with.
