

FLUID MECHANICS AND ITS APPLICATIONS

V.V. Aristov

**Direct Methods for Solving
the Boltzmann Equation
and Study of
Nonequilibrium Flows**

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Methods Of Direct Solving The Boltzmann Equation And Study Of Nonequilibrium Flows

Kun Xu



Methods Of Direct Solving The Boltzmann Equation And Study Of Nonequilibrium Flows:

Direct Methods for Solving the Boltzmann Equation and Study of Nonequilibrium Flows V.V. Aristov, 2001-01-31

This book is concerned with the methods of solving the nonlinear Boltzmann equation and of investigating its possibilities for describing some aerodynamic and physical problems. This monograph is a sequel to the book *Numerical direct solutions of the kinetic Boltzmann equation* in Russian which was written with F. G. Tcheremissine and published by the Computing Center of the Russian Academy of Sciences some years ago. The main purposes of these two books are almost similar, namely the study of nonequilibrium gas flows on the basis of direct integration of the kinetic equations. Nevertheless, there are some new aspects in the way this topic is treated in the present monograph. In particular, attention is paid to the advantages of the Boltzmann equation as a tool for considering nonequilibrium nonlinear processes. New fields of application of the Boltzmann equation are also described. Solutions of some problems are obtained with higher accuracy. Numerical procedures such as parallel computing are investigated for the first time. The structure and the contents of the present book have some common features with the monograph mentioned above, although there are new issues concerning the mathematical apparatus developed so that the Boltzmann equation can be applied for new physical problems. Because of this, some chapters have been rewritten and checked again, and some new chapters have been added.

Direct Methods for Solving the Boltzmann Equation and Study of Nonequilibrium Flows V.V. Aristov, 2012-12-06. This book is concerned with the methods of solving the nonlinear Boltzmann equation and of investigating its possibilities for describing some aerodynamic and physical problems. This monograph is a sequel to the book *Numerical direct solutions of the kinetic Boltzmann equation* in Russian which was written with F. G. Tcheremissine and published by the Computing Center of the Russian Academy of Sciences some years ago. The main purposes of these two books are almost similar, namely the study of nonequilibrium gas flows on the basis of direct integration of the kinetic equations. Nevertheless, there are some new aspects in the way this topic is treated in the present monograph. In particular, attention is paid to the advantages of the Boltzmann equation as a tool for considering nonequilibrium nonlinear processes. New fields of application of the Boltzmann equation are also described. Solutions of some problems are obtained with higher accuracy. Numerical procedures such as parallel computing are investigated for the first time. The structure and the contents of the present book have some common features with the monograph mentioned above, although there are new issues concerning the mathematical apparatus developed so that the Boltzmann equation can be applied for new physical problems. Because of this, some chapters have been rewritten and checked again, and some new chapters have been added.

Computational Fluid Dynamics 2006 Herman Deconinck, E. Dick, 2009-08-04. The International Conference on Computational Fluid Dynamics (ICCFD) is the merger of the International Conference on Numerical Methods in Fluid Dynamics (ICNMFD) since 1969 and International Symposium on Computational Fluid Dynamics (ISCFD) since 1985. It is held every two years and brings together physicists, mathematicians, and engineers to review and share recent advances in

mathematical and computational techniques for modeling fluid dynamics The proceedings of the 2006 conference ICCFD4 held in Gent Belgium contain a selection of refereed contributions and are meant to serve as a source of reference for all those interested in the state of the art in computational fluid mechanics *Discontinuous Finite Elements in Fluid Dynamics and Heat Transfer* Ben Q. Li, 2006-06-29 Over the past several years significant advances have been made in developing the discontinuous Galerkin finite element method for applications in fluid flow and heat transfer Certain unique features of the method have made it attractive as an alternative for other popular methods such as finite volume and finite elements in thermal fluids engineering analyses This book is written as an introductory textbook on the discontinuous finite element method for senior undergraduate and graduate students in the area of thermal science and fluid dynamics It also can be used as a reference book for researchers and engineers who intend to use the method for research in computational fluid dynamics and heat transfer A good portion of this book has been used in a course for computational fluid dynamics and heat transfer for senior undergraduate and first year graduate students It also has been used by some graduate students for self study of the basics of discontinuous finite elements This monograph assumes that readers have a basic understanding of thermodynamics fluid mechanics and heat transfer and some background in numerical analysis Knowledge of continuous finite elements is not necessary but will be helpful The book covers the application of the method for the simulation of both macroscopic and micro nanoscale fluid flow and heat transfer phenomena **Rarefied Gas Dynamics** Lei Wu, 2022-09-09 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 *Modeling and Computational Methods for Kinetic Equations* Pierre Degond, Lorenzo Pareschi, Giovanni Russo, 2012-12-06 In recent years kinetic theory has developed in many areas of the physical sciences and engineering and has extended the borders of its traditional fields of application New applications in traffic flow engineering granular media modeling and polymer and phase transition physics have resulted in new numerical algorithms which depart from traditional stochastic Monte Carlo methods This monograph is a self contained presentation of such recently developed aspects of kinetic theory as well as a comprehensive account of the fundamentals of the theory

Emphasizing modeling techniques and numerical methods the book provides a unified treatment of kinetic equations not found in more focused theoretical or applied works The book is divided into two parts Part I is devoted to the most fundamental kinetic model the Boltzmann equation of rarefied gas dynamics Additionally widely used numerical methods for the discretization of the Boltzmann equation are reviewed the Monte Carlo method spectral methods and finite difference methods Part II considers specific applications plasma kinetic modeling using the Landau Fokker Planck equations traffic flow modeling granular media modeling quantum kinetic modeling and coagulation fragmentation problems Modeling and Computational Methods of Kinetic Equations will be accessible to readers working in different communities where kinetic theory is important graduate students researchers and practitioners in mathematical physics applied mathematics and various branches of engineering The work may be used for self study as a reference text or in graduate level courses in kinetic theory and its applications

IUTAM Symposium on Advances in Mathematical Modelling of Atmosphere and Ocean Dynamics P.F. Hodnett, 2012-12-06 The goals of the Symposium were to highlight advances in modelling of atmosphere and ocean dynamics to provide a forum where atmosphere and ocean scientists could present their latest research results and learn of progress and promising ideas in these allied disciplines to facilitate interaction between theory and applications in atmosphere ocean dynamics These goals were seen to be especially important in view of current efforts to model climate requiring models which include interaction between atmosphere ocean and land influences Participants were delighted with the diversity of the scientific programme the opportunity to meet fellow scientists from the other discipline either atmosphere or ocean with whom they do not normally interact through their own discipline the opportunity to meet scientists from many countries other than their own the opportunity to hear significant presentations 50 minutes from the keynote speakers on a range of relevant topics Certainly the goal of creating a forum for exchange between atmosphere and ocean scientists who need to input to create realistic models for climate prediction was achieved by the Symposium and this goal will hopefully be further advanced by the publication of these Proceedings

Advances in the Mechanics of Plates and Shells D.

Durban, Dan Givoli, J.G. Simmonds, 2006-04-11 The optimal control of flexible structures is an active area of research The main body of work in this area is concerned with the control of time dependent displacements and stresses and assumes linear elastic conditions namely linear elastic material behavior and small deformation See e.g. 1-3 the collections of papers 4-5 and references therein On the other hand in the present paper we consider the static optimal control of a structure made of a nonlinear elastic material and undergoing large deformation An important application is the suppression of static or quasi-static elastic deformation in flexible space structures such as parts of satellites by the use of control loads 6 Solar radiation and radiation from other sources induce a temperature field in the structure which in turn generates an elastic displacement field The displacements must usually satisfy certain limitations dictated by the allowed working conditions of various orientation sensitive instruments and antennas in the space vehicle For example a parabolic reflector may cease to be

effective when undergoing large deflection The elastic deformation can be reduced by use of control loads which may be implemented via mechanically based actuators or more modern piezoelectric devices When the structure under consideration is made of a rubber like material and is undergoing large deformation nonlinear material and geometric effects must be taken into account in the analysis

Advances in Turbulence XII Bruno Eckhardt, 2010-03-17 This volume comprises the communications presented at the EUROMECH European Turbulence Conference ETC12 held in Marburg in September 2009 The topics covered by the meeting include Acoustics of turbulent flows Atmospheric turbulence Control of turbulent flows Geophysical and astrophysical turbulence Instability and transition Intermittency and scaling Large eddy simulation and related techniques Lagrangian aspects MHD turbulence Reacting and compressible turbulence Transport and mixing Turbulence in multiphase and non Newtonian flows Vortex dynamics and structure formation Wall bounded flows

NASA Technical Note, 1975

Lattice Boltzmann Method and Its Applications in Engineering Zhaoli Guo, Chang Shu, 2013 This book covers the fundamental and practical application of the Lattice Boltzmann method LBM This method is a relatively new simulation technique for the modeling of complex fluid systems and has attracted interest from researchers in computational physics

Direct Modeling For Computational Fluid Dynamics: Construction And Application Of Unified Gas-kinetic Schemes Kun Xu, 2014-12-23 Computational fluid dynamics CFD studies the flow motion in a discretized space Its basic scale resolved is the mesh size and time step The CFD algorithm can be constructed through a direct modeling of flow motion in such a space This book presents the principle of direct modeling for the CFD algorithm development and the construction unified gas kinetic scheme UGKS The UGKS accurately captures the gas evolution from rarefied to continuum flows Numerically it provides a continuous spectrum of governing equation in the whole flow regimes

Transport Equations for Semiconductors Ansgar Jüngel, 2009-03-17 This volume presents a systematic and mathematically accurate description and derivation of transport equations in solid state physics in particular semiconductor devices

Direct and Large-Eddy Simulation IV Bernard Geurts, Rainer Friedrich, Olivier Métais, 2013-06-29 The workshop Direct and Large Eddy Simulation 4 was held at the University of Twente July 18 20 2001 DLES4 is part of a series of ERCOFTAC workshops that originated at the University of Surrey in 1994 Over the years the DLES series has grown into a major international venue focused on the development and application of direct and large eddy simulation Fundamental turbulence and modeling issues but also elements from modern numerical analysis are at the heart of this field of interest a fact which is clearly reflected by the contents of these proceedings Modeling and simulation of complex flow phenomena forms a central element in a large volume of scientific and applied research The problem of simulating turbulent flows and capturing their main dynamical features remains a highly motivating challenge This three day workshop focused on recent developments in numerical and physical modeling of complex flow phenomena concentrating on modern strategies in the field of direct and large eddy simulation A major aim was to promote the exchange of ideas and problems from both industrial and academic background paying

attention to physical mathematical and engineering aspects

Non-equilibrium Evaporation and Condensation

Processes Yuri B. Zudin, 2021-02-27 This present book is concerned with analytical approaches to statement and solution of problems of non equilibrium evaporation and condensation From analytical solutions one is capable to understand and represent in a transparent form the principal laws especially in the study of a new phenomenon or a process This is why analytical methods are always employed on the first stage of mathematical modeling Analytical solutions are also used as test models for validation of results numerical solutions Non equilibrium evaporation and condensation processes play an important role in a number of fundamental and applied problems laser methods for processing of materials depressurization of the protection cover of nuclear propulsion units solar radiation on a comet surface explosive boiling of superheated liquid thermodynamic principles of superfluid helium Analytical relations provide an adequate description of the essence of a physical phenomenon

A Unified Computational Fluid Dynamics Framework from Rarefied to Continuum

Regimes Kun Xu, 2021-06-10 This Element presents a unified computational fluid dynamics framework from rarefied to continuum regimes The framework is based on the direct modelling of flow physics in a discretized space The mesh size and time step are used as modelling scales in the construction of discretized governing equations With the variation of cell Knudsen number continuous modelling equations in different regimes have been obtained and the Boltzmann and Navier Stokes equations become two limiting equations in the kinetic and hydrodynamic scales The unified algorithms include the discrete velocity method DVM based unified gas kinetic scheme UGKS the particlebased unified gas kinetic particle method UGKP and the wave and particle based unified gas kinetic wave particle method UGKWP The UGKWP is a multi scale method with the particle for non equilibrium transport and wave for equilibrium evolution The particle dynamics in the rarefied regime and the hydrodynamic flow solver in the continuum regime have been unified according to the cell's Knudsen number

Kinetic Theory and Swarming Tools to Modeling Complex Systems—Symmetry problems in the Science of

Living Systems Nicola Bellomo, 2020-05-29 This MPDI book comprises a number of selected contributions to a Special Issue devoted to the modeling and simulation of living systems based on developments in kinetic mathematical tools The focus is on a fascinating research field which cannot be tackled by the approach of the so called hard sciences specifically mathematics without the invention of new methods in view of a new mathematical theory The contents proposed by eight contributions witness the growing interest of scientists this field The first contribution is an editorial paper which presents the motivations for studying the mathematics and physics of living systems within the framework an interdisciplinary approach where mathematics and physics interact with specific fields of the class of systems object of modeling and simulations The different contributions refer to economy collective learning cell motion vehicular traffic crowd dynamics and social swarms The key problem towards modeling consists in capturing the complexity features of living systems All articles refer to large systems of interaction living entities and follow towards modeling a common rationale which consists firstly in representing the system

by a probability distribution over the microscopic state of the said entities secondly in deriving a general mathematical structure deemed to provide the conceptual basis for the derivation of models and finally in implementing the said structure by models of interactions at the microscopic scale Therefore the modeling approach transfers the dynamics at the low scale to collective behaviors Interactions are modeled by theoretical tools of stochastic game theory Overall the interested reader will find in the contents a forward look comprising various research perspectives and issues followed by hints on to tackle these

GPU Computing Gems Jade Edition ,2011-11-02 GPU Computing Gems Jade Edition offers hands on proven techniques for general purpose GPU programming based on the successful application experiences of leading researchers and developers One of few resources available that distills the best practices of the community of CUDA programmers this second edition contains 100% new material of interest across industry including finance medicine imaging engineering gaming environmental science and green computing It covers new tools and frameworks for productive GPU computing application development and provides immediate benefit to researchers developing improved programming environments for GPUs Divided into five sections this book explains how GPU execution is achieved with algorithm implementation techniques and approaches to data structure layout More specifically it considers three general requirements high level of parallelism coherent memory access by threads within warps and coherent control flow within warps Chapters explore topics such as accelerating database searches how to leverage the Fermi GPU architecture to further accelerate prefix operations and GPU implementation of hash tables There are also discussions on the state of GPU computing in interactive physics and artificial intelligence programming tools and techniques for GPU computing and the edge and node parallelism approach for computing graph centrality metrics In addition the book proposes an alternative approach that balances computation regardless of node degree variance Software engineers programmers hardware engineers and advanced students will find this book extremely usefull For useful source codes discussed throughout the book the editors invite readers to the following website This second volume of GPU Computing Gems offers 100% new material of interest across industry including finance medicine imaging engineering gaming environmental science green computing and more Covers new tools and frameworks for productive GPU computing application development and offers immediate benefit to researchers developing improved programming environments for GPUs Even more hands on proven techniques demonstrating how general purpose GPU computing is changing scientific research Distills the best practices of the community of CUDA programmers each chapter provides insights and ideas as well as hands on skills applicable to a variety of fields

IUTAM Symposium on Free Surface Flows A.C. King,Y.D. Shikhmurzaev,2012-12-06 Free surface flows arise in the natural world physical and biological sciences and in some areas of modern technology and engineering Exam ples include the breaking of sea waves on a harbour wall the transport of sloshing fluids in partly filled containers and the design of micronozzles for high speed ink jet printing Apart from the intrinsic mathematical challenge in describing and solving the governing equations there are usually important

environmental safety and engineering features which need to be analysed and controlled A rich variety of techniques has been developed over the past two decades to facilitate this analysis singular perturbations dynamical systems and the development of sophisticated numerical codes The extreme and sometimes violent nature of some free surface flows taxes these methods to the limit The work presented at the symposium addressed these limits and can be loosely classified into four areas i Axisymmetric free surface flows There are a variety of problems in the printing glass fertiliser and fine chemical industries in which threads of fluid are made and controlled Presentations were made in the areas of pinch off for inviscid and viscous threads of fluid recoil effects after droplet formation and the control of instability by forced vibration ii Dynamic wetting The motion of three phase contact lines which are formed at the junction between two fluids and a solid plays an important role in fluid mechanics AIAA Aerospace Sciences Meeting and Exhibit, 42nd ,2004

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