

*Modeling and Simulation in  
Science, Engineering and Technology*

# Modeling and Computational Methods for Kinetic Equations

*Pierre Degond  
Lorenzo Pareschi  
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*Editors*

B I R K H Ä U S E R

# Modeling And Computational Methods For Kinetic Equations

**F. Ceragioli, A. Dontchev, H. Furuta, L. Pandolfi**



## **Modeling And Computational Methods For Kinetic Equations:**

Modeling and Computational Methods for Kinetic Equations Pierre Degond, Lorenzo Pareschi, Giovanni Russo, 2004-04-07

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.

**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

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**Modeling and Computational Methods for Multi-scale Quantum Dynamics and Kinetic Equations**, 2013 This dissertation consists of two parts quantum transitions Part 1 and hydrodynamic limits of kinetic equations Part 2 In both parts we investigate the inner mathematical connections between equations for different physics at different scales and use these connections to design efficient computational methods for multi scale problems Despite its numerous applications in chemistry and physics the mathematics of quantum transition is not well understood Using the Wigner transformation we derive semi classical models in phase space for two problems the dynamics of electrons in crystals near band crossing points surface hopping of quantum molecules when the Born Oppenheimer approximation breaks down In both cases particles may jump between states with comparable energies Our models can capture the transition rates for such processes We provide analytic analysis of and numerical methods for our models demonstrated by explicit examples The second part is to construct numerical methods for kinetic equation that are efficient in the hydrodynamic regime Asymptotically the kinetic equations reduce to fluid dynamics described by the Euler or Navier Stokes equations in the fluid regime Numerically the Boltzmann equation is still hard to handle in the hydrodynamic regime due to the stiff collision term We review the theoretical work that links the two sets of equations and present our asymptotic preserving numerical solvers for the Boltzmann equation that naturally capture the asymptotic limits in the hydrodynamic regime We also extend our methods to the case of multi species systems *Modeling Approaches and Computational Methods for Particle-laden Turbulent Flows* Shankar Subramaniam, S.

Balachandar, 2022-10-20 Modelling Approaches and Computational Methods for Particle laden Turbulent Flows introduces the principal phenomena observed in applications where turbulence in particle laden flow is encountered while also analyzing the main methods for analyzing numerically The book takes a practical approach providing advice on how to select and apply the correct model or tool by drawing on the latest research Sections provide scales of particle laden turbulence and the principal analytical frameworks and computational approaches used to simulate particles in turbulent flow Each chapter opens with a section on fundamental concepts and theory before describing the applications of the modelling approach or numerical method Featuring explanations of key concepts definitions and fundamental physics and equations as well as recent research advances and detailed simulation methods this book is the ideal starting point for students new to this subject as well as an essential reference for experienced researchers Provides a comprehensive introduction to the phenomena of particle laden turbulent flow Explains a wide range of numerical methods including Eulerian Eulerian Eulerian Lagrange and volume filtered computation Describes a wide range of innovative applications of these models *Uncertainty Quantification for Hyperbolic and Kinetic Equations* Shi Jin, Lorenzo Pareschi, 2018-03-20 This book explores recent advances in uncertainty quantification for hyperbolic kinetic and related problems The contributions address a range of different aspects including polynomial chaos expansions perturbation methods multi level Monte Carlo methods importance sampling

and moment methods The interest in these topics is rapidly growing as their applications have now expanded to many areas in engineering physics biology and the social sciences Accordingly the book provides the scientific community with a topical overview of the latest research efforts      *Landau Equation, Boltzmann-type Equations, Discrete Models, and Numerical Methods* Alexander V. Bobylev, 2024-09-23 This two volume monograph is a comprehensive and up to date presentation of the theory and applications of kinetic equations The second volume covers discrete velocity models of the Boltzmann equation results on the Landau equation and numerical deterministic and stochastic methods for the solution of kinetic equations

Advances in Computational Methods in Sciences and Engineering 2005 (2 vols) Theodore Simos, George Maroulis, 2022-05-04 This volume brings together selected contributed papers presented at the International Conference of Computational Methods in Science and Engineering ICCMSE 2005 held in Greece 21 aEURO 26 October 2005 The conference aims to bring together computational scientists from several disciplines in order to share methods and ideas The ICCMSE is unique in its kind It regroups original contributions from all fields of the traditional Sciences Mathematics Physics Chemistry Biology Medicine and all branches of Engineering It would be perhaps more appropriate to define the ICCMSE as a conference on computational science and its applications to science and engineering Topics of general interest are Computational Mathematics Theoretical Physics and Theoretical Chemistry Computational Engineering and Mechanics Computational Biology and Medicine Computational Geosciences and Meteorology Computational Economics and Finance Scientific Computation High Performance Computing Parallel and Distributed Computing Visualization Problem Solving Environments Numerical Algorithms Modelling and Simulation of Complex System Web based Simulation and Computing Grid based Simulation and Computing Fuzzy Logic Hybrid Computational Methods Data Mining Information Retrieval and Virtual Reality Reliable Computing Image Processing Computational Science and Education etc More than 800 extended abstracts have been submitted for consideration for presentation in ICCMSE 2005 From these 500 have been selected after international peer review by at least two independent reviewers      Monte Carlo and Quasi-Monte Carlo Methods Bruno Tuffin, Pierre L'Ecuyer, 2020-05-01 This book presents the refereed proceedings of the 13th International Conference on Monte Carlo and Quasi Monte Carlo Methods in Scientific Computing that was held at the University of Rennes France and organized by Inria in July 2018 These biennial conferences are major events for Monte Carlo and quasi Monte Carlo researchers The proceedings include articles based on invited lectures as well as carefully selected contributed papers on all theoretical aspects and applications of Monte Carlo and quasi Monte Carlo methods Offering information on the latest developments in these very active areas this book is an excellent reference resource for theoreticians and practitioners interested in solving high dimensional computational problems arising in particular in finance statistics and computer graphics      **Computational Methods for Polymers** Masoud Soroush, 2020-12-10 This book presents recent advances in computational methods for polymers It covers multiscale modeling of polymers polymerization reactions and polymerization

processes as well as control monitoring and estimation methods applied to polymerization processes It presents theoretical insights gained from multiscale modeling validated with experimental measurements The book consolidates new computational tools and methods developed by academic researchers in this area and presents them systematically The book is useful for graduate students researchers and process engineers and managers

**Handbook of Numerical Methods for Hyperbolic Problems** Remi Abgrall, Chi-Wang Shu, 2017-01-16 Handbook on Numerical Methods for Hyperbolic Problems Applied and Modern Issues details the large amount of literature in the design analysis and application of various numerical algorithms for solving hyperbolic equations that has been produced in the last several decades This volume provides concise summaries from experts in different types of algorithms so that readers can find a variety of algorithms under different situations and become familiar with their relative advantages and limitations Provides detailed cutting edge background explanations of existing algorithms and their analysis Presents a method of different algorithms for specific applications and the relative advantages and limitations of different algorithms for engineers or those involved in applications Written by leading subject experts in each field the volumes provide breadth and depth of content coverage

Computational Methods in Multiphase Flow V Andrea Alberto Mammoli, C. A. Brebbia, 2009 Together with turbulence multiphase flow remains one of the most challenging areas of computational mechanics and experimental methods and numerous problems remain unsolved to date Multiphase flows are found in all areas of technology at all length scales and flow regimes The fluids involved can be compressible or incompressible linear or nonlinear Because of the complexity of the problems it is often essential to utilize advanced computational and experimental methods to solve the complex equations that describe them Challenges in these simulations include modelling and tracking interfaces dealing with multiple length scales modelling nonlinear fluids treating drop breakup and coalescence characterizing phase structures and many others Experimental techniques although expensive and difficult to perform are essential to validate models This book contains papers presented at the Fifth International Conference on Computational Methods in Multiphase Flow which are grouped into the following topics Multiphase Flow Simulation Interaction of Gas Liquids and Solids Turbulent Flow Environmental Multiphase Flow Bubble and Drop Dynamics Flow in Porous Media Heat Transfer Image Processing Interfacial Behaviour

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needs and demonstrate how to identify stiff terms and effectively implement high order methods in time for a variety of systems of PDEs Readers interested in learning modern techniques for the effective numerical solution of evolutionary PDEs with multiple time scales will find in this book a unified compact and accessible treatment This book is intended for applied mathematicians scientists and engineers who use or are interested in learning about IMEX schemes Readers should have some background in numerical methods for ODE systems and basic finite difference and finite volume discretization of evolutionary PDEs along with a basic understanding of the relevant mathematical models The book is suitable for students who have had a basic course in numerical analysis and are familiar with partial differential equations *Mathematical and Computational Approaches in Advancing Modern Science and Engineering* Jacques Bélair, Ian A. Frigaard, Herb Kunze, Roman Makarov, Roderick Melnik, Raymond J. Spiteri, 2016-08-10 Focusing on five main groups of interdisciplinary problems this book covers a wide range of topics in mathematical modeling computational science and applied mathematics It presents a wealth of new results in the development of modeling theories and methods advancing diverse areas of applications and promoting interdisciplinary interactions between mathematicians scientists engineers and representatives from other disciplines The book offers a valuable source of methods ideas and tools developed for a variety of disciplines including the natural and social sciences medicine engineering and technology Original results are presented on both the fundamental and applied level accompanied by an ample number of real world problems and examples emphasizing the interdisciplinary nature and universality of mathematical modeling and providing an excellent outline of today's challenges Mathematical modeling with applied and computational methods and tools plays a fundamental role in modern science and engineering It provides a primary and ubiquitous tool in the context making new discoveries as well as in the development of new theories and techniques for solving key problems arising in scientific and engineering applications The contributions which are the product of two highly successful meetings held jointly in Waterloo Ontario Canada on the main campus of Wilfrid Laurier University in June 2015 i e the International Conference on Applied Mathematics Modeling and Computational Science and the Annual Meeting of the Canadian Applied and Industrial Mathematics CAIMS make the book a valuable resource for any reader interested in a broader overview of the methods ideas and tools involved in mathematical and computational approaches developed for other disciplines including the natural and social sciences engineering and technology

**COMPUTATIONAL MODELS - Volume I** Shaidurov Vladimir Viktorovich, 2009-04-10 Computational Models is a component of Encyclopedia of Mathematical Sciences in the global Encyclopedia of Life Support Systems EOLSS which is an integrated compendium of twenty one Encyclopedias Modern Computational Mathematics arises in a wide variety of fields including business economics engineering finance medicine and science The Theme on Computational Models provides the essential aspects of Computational Mathematics emphasizing Basic Methods for Solving Equations Numerical Analysis and Methods for Ordinary Differential Equations Numerical Methods and Algorithms Computational Methods and Algorithms

Numerical Models and Simulation These two volumes are aimed at those seeking in depth of advanced knowledge University and College students Educators Professional practitioners Research personnel and Policy analysts managers and decision makers and NGOs

*Nonlinear Hyperbolic Problems: Theoretical, Applied, and Computational Aspects* Andrea Donato, Francesco Oliveri, 2013-03-08 *Mathematical Reviews*, 2005 Computational Methods in Transport: Verification and Validation Frank Graziani, 2008-08-09 The focus of this book deals with a cross cutting issue affecting all transport disciplines whether it be photon neutron charged particle or neutrino transport That is verification and validation In this book we learn what the astrophysicist atmospheric scientist mathematician or nuclear engineer do to assess the accuracy of their code What convergence studies what error analysis what problems do each field use to ascertain the accuracy of their transport simulations

Numerical Methods for Hyperbolic Equations Elena Vázquez-Cendón, Arturo Hidalgo, Pilar Garcia Navarro, Luis Cea, 2012-11-05 Numerical Methods for Hyperbolic Equations is a collection of 49 articles presented at the International Conference on Numerical Methods for Hyperbolic Equations Theory and Applications Santiago de Compostela Spain 4-8 July 2011 The conference was organized to honour Professor Eleuterio Toro in the month of his 65th birthday The topics cover

**Multiphysics Modeling: Numerical Methods and Engineering Applications** Qun Zhang, Song Cen, 2015-12-15 Multiphysics Modeling Numerical Methods and Engineering Applications Tsinghua University Press Computational Mechanics Series describes the basic principles and methods for multiphysics modeling covering related areas of physics such as structure mechanics fluid dynamics heat transfer electromagnetic field and noise The book provides the latest information on basic numerical methods also considering coupled problems spanning fluid solid interaction thermal stress coupling fluid solid thermal coupling electromagnetic solid thermal fluid coupling and structure noise coupling Users will find a comprehensive book that covers background theory algorithms key technologies and applications for each coupling method Presents a wealth of multiphysics modeling methods issues and worked examples in a single volume Provides a go to resource for coupling and multiphysics problems Covers the multiphysics details not touched upon in broader numerical methods references including load transfer between physics element level strong coupling and interface strong coupling amongst others Discusses practical applications throughout and tackles real life multiphysics problems across areas such as automotive aerospace and biomedical engineering

**Computational Methods in Systems Biology** Monika Heiner, Adelinde M. Uhrmacher, 2008-10-05 This book constitutes the refereed proceedings of the 6th International Conference on Computational Methods in Systems Biology CMSB 2008 held in Rostock Germany in September 2008 The 21 revised full papers presented together with the summaries of 5 invited papers were carefully reviewed and selected from more than 60 submissions The papers cover theoretical or applied contributions that are motivated by a biological question focusing on modeling approaches including process algebra simulation approaches analysis methods in particular model checking and flux analysis and case studies

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