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Linear Partial Differential Equations for Scientists and Engineers - Tyn Myint-U 2011-03-21

It's a Nonlinear World - Richard H. Enns 2010-10-14
Drawing examples from mathematics, physics, chemistry, biology, engineering, economics, medicine, politics, and sports, this book illustrates how nonlinear dynamics plays a vital role in our world. Examples cover a wide range from the spread and possible control of communicable diseases, to the lack of predictability in long-range weather forecasting, to competition between political groups and nations. After an introductory chapter that explores what it means to be nonlinear, the book covers the mathematical concepts such as limit cycles, fractals, chaos, bifurcations, and solitons, that will be applied throughout the book. Numerous computer simulations and exercises allow students to explore topics in greater depth using the Maple computer algebra system. The mathematical level of the text assumes prior exposure to ordinary differential equations and familiarity with the wave and diffusion equations. No prior knowledge of Maple is assumed. The book may be used at the undergraduate or graduate level to prepare science and engineering students for problems in the "real world", or for self-study by practicing scientists and engineers.

A Closer Look of Nonlinear Reaction-Diffusion Equations - Lakshmanan Rajendran 2020-10
By using mathematical models to describe the physical, biological or chemical phenomena, one of the most common results is either a differential equation or a system of differential equations, together with the correct boundary and initial conditions. The determination and interpretation of their solution are at the base of applied mathematics. Hence the analytical and numerical study of the differential equation is very much essential for all theoretical and experimental researchers, and this book helps to develop skills in this area.Recently non-linear differential equations were widely used to model many of the interesting and relevant phenomena found in many fields of science and technology on a mathematical basis. This problem is to inspire them in various fields such as economics, medical biology, plasma physics, particle physics, differential geometry, engineering, signal processing, electrochemistry and materials science.This book contains seven chapters and practical applications to the problems of the real world. The first chapter is specifically for those with limited mathematical background. Chapter one presents the introduction of non-linear reaction-diffusion systems, various boundary conditions and examples. Real-life application of non-linear reaction-diffusion in different fields with some important non-linear equations is also discussed. In Chapter 2, mathematical preliminaries and various advanced methods of solving non-linear differential equations such as Homotopy perturbation method, variational iteration method, exponential function method etc. are described with examples.Steady and non-steady state reaction-diffusion equations in the plane sheet (chapter 3), cylinder (chapter 4) and spherical (chapter 5) are analyzed. The analytical results published by various researchers in referred journals during 2007-2020 have been addressed in these chapters 4 to 6, and this leads to conclusions and recommendations on what approaches to use on non-linear reaction-diffusion equations.Convection-diffusion problems arise very often in applied sciences and engineering. Non-linear convection-diffusion equations and corresponding analytical solutions in various fields of chemical sciences are discussed in chapter6. Numerical methods are used to provide approximate results for the non-linear problems, and their importance is felt when it is impossible or difficult to solve a given problem analytically. Chapter 7 identifies some of the numerical methods for finding solutions to non-linear differential equations.

Applied Nonlinear Semigroups - A. Belleni-Morante 1998-12-04
Mathematical Methods in Practice Advisory Editors Bruno Brosowski Universität Frankfurt Germany Gary F. Roach University of Strathclyde UK Volume 3 Applied Nonlinear Semigroups A. Belleni-Morante University of Florence, Italy A. C. McBride University of Strathclyde, UK In many disciplines such as physics, chemistry, biology, meteorology, electronics and economics, it is increasingly necessary to develop mathematical models that describe how the state of a system evolves with time. A useful way of studying such a model is to recast the appropriate evolution equation as an Abstract Cauchy Problem (ACP), which can then be analysed via the powerful theory of semigroups of operators. The user-friendly presentation in the book is centred on Abstract Cauchy Problems which model various processes such as particle transport,diffusion and combustion, all of which are examples of systems which evolve with time. The authors provide an introduction to the requisite concepts from functional analysis before moving on to the theory of semigroups of linear operators and their application to linear ACPs. These ideas are then applied to semilinear problems and fully nonlinear

problems and it is shown how results from the linear theory can be extended. Finally, a variety of applications of practical interest are included. By leading a non-expert to the solutions of problems involving evolution equations via the theory of semigroups of operators, both linear and nonlinear, the book provides an accessible introduction to the treatment of the subject. The reader is assumed to have a basic knowledge of real analysis and vector spaces. M.Sc. and graduate students of functional analysis, applied mathematics, physics and engineering will find this an invaluable introduction to the subject.

Superlinear Parabolic Problems - Prof. Dr. Pavol Quittner 2019-06-13

This book is devoted to the qualitative study of solutions of superlinear elliptic and parabolic partial differential equations and systems. This class of problems contains, in particular, a number of reaction-diffusion systems which arise in various mathematical models, especially in chemistry, physics and biology. The first two chapters introduce to the field and enable the reader to get acquainted with the main ideas by studying simple model problems, respectively of elliptic and parabolic type. The subsequent three chapters are devoted to problems with more complex structure; namely, elliptic and parabolic systems, equations with gradient depending nonlinearities, and nonlocal equations. They include many developments which reflect several aspects of current research. Although the techniques introduced in the first two chapters provide efficient tools to attack some aspects of these problems, they often display new phenomena and specifically different behaviors, whose study requires new ideas. Many open problems are mentioned and commented. The book is self-contained and up-to-date, it has a high didactic quality. It is devoted to problems that are intensively studied but have not been treated so far in depth in the book literature. The intended audience includes graduate and postgraduate students and researchers working in the field of partial differential equations and applied mathematics. The first edition of this book has become one of the standard references in the field. This second edition provides a revised text and contains a number of updates reflecting significant recent advances that have appeared in this growing field since the first edition.

Nonlinear PDEs - Marius Ghergu 2011-10-22

The emphasis throughout the present volume is on the practical application of theoretical mathematical models helping to unravel the underlying mechanisms involved in processes from mathematical physics and biosciences. It has been conceived as a unique collection of abstract methods dealing especially with nonlinear partial differential equations (either stationary or evolutionary) that are applied to understand concrete processes involving some important applications related to phenomena such as: boundary layer phenomena for viscous fluids, population dynamics,, dead core phenomena, etc. It addresses researchers and post-graduate students working at the interplay between mathematics and other fields of science and technology and is a comprehensive introduction to the theory of nonlinear partial differential equations and its main principles also presents their real-life applications in various contexts: mathematical physics, chemistry, mathematical biology, and population genetics. Based on the authors' original work, this volume provides an overview of the field, with examples suitable for researchers but also for graduate students entering research. The method of presentation appeals to readers with diverse backgrounds in partial differential equations and functional analysis. Each chapter includes detailed heuristic arguments, providing thorough motivation for the material developed later in the text. The content demonstrates in a firm way that partial differential equations can be used to address a large variety of phenomena occurring in and influencing our daily lives. The extensive reference list and index make this book a valuable resource for researchers working in a variety of fields and who are interested in phenomena modeled by nonlinear partial differential equations.

Handbook of Applied Analysis - Nikolaos S. Papageorgiou 2009-05-31

This handbook provides an in-depth examination of important theoretical methods and procedures in applied analysis. It details many of the most important theoretical trends in nonlinear analysis and applications to different fields. These features make the volume a valuable tool for every researcher working on nonlinear analysis.

Smoothing and Decay Estimates for Nonlinear Diffusion Equations - Juan Luis Vázquez 2006-08-03

This text is concerned with quantitative aspects of the theory of nonlinear diffusion equations, whichappear as mathematical models in different branches of Physics, Chemistry, Biology and Engineering.

Model Based Parameter Estimation - Hans Georg Bock 2013-02-26

This judicious selection of articles combines mathematical and numerical methods to apply parameter estimation and optimum experimental design in a range of contexts. These include fields as diverse as biology, medicine, chemistry, environmental physics, image processing and computer vision. The material chosen was presented at a multidisciplinary workshop on parameter estimation held in 2009 in Heidelberg. The contributions show how indispensable efficient methods of applied mathematics and computer-based modeling can be to enhancing the quality of interdisciplinary research. The use of scientific computing to model, simulate, and optimize complex processes has become a standard methodology in many scientific fields, as well as in industry. Demonstrating that the use of state-of-the-art optimization techniques in a number of research areas has much potential for improvement, this book provides advanced numerical methods and the very latest results for the applications under consideration.

<u>Nonlinear Reaction-Diffusion-Convection Equations</u> - Roman Cherniha 2017-11-02

It is well known that symmetry-based methods are very powerful tools for investigating nonlinear partial differential equations (PDEs), notably for their reduction to those of lower dimensionality (e.g. to ODEs) and constructing exact solutions. This book is devoted to (1) search Lie and conditional (non-classical) symmetries of nonlinear RDC equations, (2) constructing exact solutions using the symmetries obtained, and (3) their applications for solving some biologically and physically motivated problems. The book summarises the results derived by the authors during the last 10 years and those obtained by some other authors.

<u>Stochastic Numerics for Mathematical Physics</u> - Grigori Noah Milstein 2014-01-15

<u>Implicit Partial Differential Equations</u> - Bernard Dacorogna 1999-08-01

Nonlinear partial differential equations has become one of the main tools of mod ern mathematical analysis; in spite of seemingly contradictory terminology, the subject of nonlinear differential equations finds its origins in the theory of linear differential equations, and a large part of functional analysis derived its inspiration from the study of linear pdes. In recent years, several mathematicians have investigated nonlinear equations, particularly those of the second order, both linear and nonlinear and either in divergence or nondivergence form. Quasilinear and fully nonlinear differential equations are relevant classes of such equations and have been widely examined in the mathematical literature. In this work we present a new family of differential equations called "implicit partial differential equations", described in detail in the introduction (c.f. Chapter 1). It is a class of nonlinear equations that does not include the family of fully nonlinear elliptic pdes. We present a new functional analytic method based on the Baire category theorem for handling the existence of almost everywhere solutions of these implicit equations. The results have been obtained for the most part in recent years and have important applications to the calculus of variations, nonlin ear elasticity, problems of phase transitions and optimal design; some results have not been published elsewhere.

Numerical Continuation and Bifurcation in Nonlinear PDEs - Hannes Uecker 2021-08-19

This book provides a hands-on approach to numerical continuation and bifurcation for nonlinear PDEs in 1D, 2D, and 3D. Partial differential equations (PDEs) are the main tool to describe spatially and temporally extended systems in nature. PDEs usually come with parameters, and the study of the parameter dependence of their solutions is an important task. Letting one parameter vary typically yields a branch of solutions, and at special parameter values, new branches may bifurcate. After a concise review of some analytical background and numerical methods, the author explains the free MATLAB package pde2path by using a large variety of examples with demo codes that can be easily adapted to the reader's given problem. Numerical Continuation and Bifurcation in Nonlinear PDEs will appeal to applied mathematicians and scientists from physics, chemistry, biology, and economics interested in the numerical solution of nonlinear PDEs, particularly the parameter dependence of solutions. It can be used as a supplemental text in courses on nonlinear PDEs and modeling and bifurcation.

Differential Equation Analysis in Biomedical Science and Engineering - William E. Schiesser 2014-03-31

Features a solid foundation of mathematical and computational tools to formulate and solve real-world PDE problems across various fields With a step-by-step approach to solving partial differential equations (PDEs), Differential Equation Analysis in Biomedical Science and Engineering: Partial Differential Equation Applications with R successfully applies computational techniques for solving real-world PDE problems that are found in a variety of fields, including chemistry, physics, biology, and physiology. The book provides readers with the necessary knowledge to reproduce and extend the computed numerical solutions and is a valuable resource for dealing with a broad class of linear and nonlinear partial differential equations. The author’s primary focus is on models expressed as systems of PDEs, which generally result from including spatial effects so that the PDE dependent variables are functions of both space and time, unlike ordinary differential equation (ODE) systems that pertain to time only. As such, the book emphasizes details of the numerical algorithms and how the solutions were computed. Featuring computer-based mathematical models for solving real-world problems in the biological and biomedical sciences and engineering, the book also includes: R routines to facilitate the immediate use of computation for solving differential equation problems without having to first learn the basic concepts of numerical analysis and programming for PDEs Models as systems of PDEs and associated initial and boundary conditions with explanations of the associated chemistry, physics, biology, and physiology Numerical solutions of the presented model equations with a discussion of the important features of the solutions Aspects of general PDE computation through various biomedical science and engineering applications Differential Equation Analysis in Biomedical Science and Engineering: Partial Differential Equation Applications with R is an excellent reference for researchers, scientists, clinicians, medical researchers, engineers, statisticians, epidemiologists, and pharmacokineticists who are interested in both clinical applications and interpretation of experimental data with mathematical models in order to efficiently solve the associated differential equations. The book is also useful as a textbook for graduate-level courses in mathematics, biomedical science and engineering, biology, biophysics, biochemistry, medicine, and engineering.

Nonlinear PDEs - Marius Ghergu 2011-10-29

The emphasis throughout the present volume is on the practical application of theoretical mathematical models helping to unravel the underlying mechanisms involved in processes from mathematical physics and biosciences. It has been conceived as a unique collection of abstract methods dealing especially with nonlinear partial differential equations (either stationary or evolutionary) that are applied to understand concrete processes involving some important applications related to phenomena such as: boundary layer phenomena for viscous fluids, population dynamics,, dead core phenomena, etc. It addresses researchers and post-graduate students working at the interplay between mathematics and other fields of science and technology and is a comprehensive introduction to the theory of nonlinear partial differential equations and its main principles also presents their real-life applications in various contexts: mathematical physics, chemistry, mathematical biology, and population genetics. Based on the authors' original work, this volume provides an overview of the field, with examples suitable for researchers but also for graduate students entering research. The method of presentation appeals to readers with diverse backgrounds in partial differential equations and functional analysis. Each chapter includes detailed heuristic arguments, providing thorough motivation for the material developed later in the text. The content demonstrates in a firm way that partial differential equations can be used to address a large variety of phenomena occurring in and influencing our daily lives. The extensive reference list and index make this book a valuable resource for researchers working in a variety of fields and who are interested in phenomena modeled by nonlinear partial differential equations.

Special Functions and Analysis of Differential Equations - Praveen Agarwal 2020-09-08

Differential Equations are very important tools in Mathematical Analysis. They are widely found in mathematics itself and in its applications to statistics, computing, electrical circuit analysis, dynamical systems, economics, biology, and so on. Recently there has been an increasing interest in and widely-extended use of differential equations and systems of fractional order (that is, of arbitrary order) as better models of phenomena in various physics, engineering, automatization, biology and biomedicine, chemistry, earth science, economics, nature, and so on. Now, new unified presentation and extensive development of special functions associated with fractional calculus are necessary tools, being related to the theory of differentiation and integration of arbitrary order (i.e., fractional calculus) and to the fractional order (or multi-order) differential and integral equations. This book provides learners with the opportunity to develop an understanding of advancements of special functions and the skills needed to apply advanced mathematical techniques to solve complex differential equations and Partial Differential Equations (PDEs). Subject matters should be strongly related to special functions involving mathematical analysis and its numerous applications. The main objective of this book is to highlight the importance of fundamental results and techniques of the theory of complex analysis for differential equations and PDEs and emphasizes articles devoted to the mathematical treatment of questions arising in physics, chemistry, biology, and engineering, particularly those that stress analytical aspects and novel problems and their solutions. Specific topics include but are not limited to Partial differential equations Least squares on first-order system Sequence and series in functional analysis Special functions related to fractional (non-integer) order control systems and equations Various special functions related to generalized fractional calculus Operational method in fractional calculus Functional analysis and operator theory Mathematical physics Applications of numerical analysis and applied mathematics Computational mathematics Mathematical modeling This book provides the recent developments in special functions and differential equations and publishes high-quality, peer-reviewed book chapters in the area of nonlinear analysis, ordinary differential equations, partial differential equations, and related applications.

Partial Differential Equations with Variable Exponents - Vicentiu D. Radulescu 2015-06-24

Partial Differential Equations with Variable Exponents: Variational Methods and Qualitative Analysis provides researchers and graduate students with a thorough introduction to the theory of nonlinear partial differential equations (PDEs) with a variable exponent, particularly those of elliptic type. The book presents the most important variational methods for elliptic PDEs described by nonhomogeneous differential operators and containing one or more power-type nonlinearities with a variable exponent. The authors give a systematic treatment of the basic mathematical theory and constructive methods for these classes of nonlinear elliptic equations as well as their applications to various processes arising in the applied sciences. The analysis developed in the book is based on the notion of a generalized or weak solution. This approach leads not only to the fundamental results of existence and multiplicity of weak solutions but also to several qualitative properties, including spectral analysis, bifurcation, and asymptotic analysis. The book examines the equations from different points of view while using the calculus of variations as the unifying theme. Readers will see how all of these diverse topics are connected to other important parts of mathematics, including topology, differential geometry, mathematical physics, and potential theory.

Introduction to PDEs and Waves for the Atmosphere and Ocean - Andrew Majda 2003

Written by a leading specialist in the area of atmosphere/ocean science (AOS), the book presents an excellent introduction to this important topic. The goals of these lecture notes, based on courses presented by the author at the Courant Institute of Mathematical Sciences, are to introduce mathematicians to the fascinating and important area of atmosphere/ocean science (AOS) and, conversely, to develop a mathematical viewpoint on basic topics in AOS of interest to the disciplinary AOS community, ranging from graduate students to researchers. The lecture notes emphasize the serendipitous connections between applied mathematics and geophysical flows in the style of modern applied mathematics, where rigorous mathematical analysis as well as asymptotic, qualitative, and numerical modeling all interact to ease the understanding of physical phenomena. Reading these lecture notes does not require a previous course in fluid dynamics, although a serious reader should supplement these notes with material such The book is intended for graduate students and researchers working in interdisciplinary areas between mathematics and AOS. It is excellent for supplementary course reading or independent study.

The Dynamics of Patterns - M I Rabinovich 2000-10-31

Spirals, vortices, crystalline lattices, and other attractive patterns are prevalent in Nature. How do such beautiful patterns appear from the initial chaos? What universal dynamical rules are responsible for their formation? What is the dynamical origin of spatial disorder in nonequilibrium media? Based on the many visual experiments in physics, hydrodynamics, chemistry, and biology, this invaluable book answers those and related intriguing questions. The mathematical models presented for the dynamical theory of pattern formation are nonlinear partial differential equations. The corresponding theory is not so accessible to a wide audience. Consequently, the authors have made every attempt to synthesize long and complex mathematical calculations to exhibit the underlying physics. The book will be useful for final year undergraduates, but is primarily aimed at graduate students, postdoctoral fellows, and others interested in the puzzling phenomena of pattern formation. Contents:Patterns: Prelude to a Dynamical DescriptionLinear Stage of Pattern FormationModel EquationsThe Ginzburg–Landau Equation‘Crystal’ FormationQuasicrystalsBreaking of OrderLocalized PatternsSpiralsPatterns in Oscillating Soap FilmsPatterns in Colonies of MicroorganismsSpatial DisorderPatterns in Chaotic MediaEpilogue: Living Matter and Dynamic FormsA Short Guide to Nonlinear DynamicsKey Experiments in Pattern Formation Readership: Graduate students of mathematical physics and nonlinear science. Keywords:Quasicrystals;Disordered Patterns;Defects;Spirals;Turbulence;Synchronization;Convection;Capillary Waves;Chaotic Dynamics;Biological PatternsReviews: “This beautifully illustrated book brings together a remarkable array of pattern-forming phenomena … The authors have assembled an impressive collection of striking photographs and computer-generated images, and the book would be worth buying for this alone … the Appendix describing key experiments is a highlight. Here the authors outline the historical development of experiments in parametrically-excited patterns, thermal convection and diffusive chemical reactions.” UK Nonlinear News “This book contains a very impressive account of key ideas and results in nonlinear dynamics and an equally excellent description of important experiments in pattern formation … readers can gain quite comprehensive knowledge about all possible patterns and their mathematical theories by reading a single chapter, coupled with Appendix I.” Mathematical Reviews

Equilibrium Problems and Applications - Gábor Kassay 2018-10-09

Equilibrium Problems and Applications develops a unified variational approach to deal with single-valued, set-valued and quasi-equilibrium problems. The authors promote original results in relationship with classical contributions to the field of equilibrium problems. The content evolved in the general setting of topological vector spaces and it lies at the interplay between pure and applied nonlinear analysis, mathematical economics, and mathematical physics. This abstract approach is based on tools from various fields, including set-valued analysis, variational and hemivariational inequalities, fixed point theory, and optimization. Applications include models from mathematical economics, Nash equilibrium of non-cooperative games, and Browder variational inclusions. The content is self-contained and the book is mainly addressed to researchers in mathematics, economics and mathematical physics as well as to graduate students in applied nonlinear analysis. A rigorous mathematical analysis of Nash equilibrium type problems, which play a central role to describe network traffic models, competition games or problems arising in experimental economics Develops generic models relevant to mathematical economics and quantitative modeling of game theory, aiding economists to understand vital material without having to wade through complex proofs Reveals a number of surprising interactions among various equilibria topics, enabling readers to identify a common and unified approach to analysing problem sets Illustrates the deep features shared by several types of nonlinear problems, encouraging readers to develop further this unifying approach from other viewpoints into economic models in turn

Boundary Stabilization of Parabolic Equations - Ionuţ Munteanu 2019-02-15

This monograph presents a technique, developed by the author, to design asymptotically exponentially stabilizing finite-dimensional boundary proportional-type feedback controllers for nonlinear parabolic-type equations. The potential control applications of this technique are wide ranging in many research areas, such as Newtonian fluid flows modeled by the Navier-Stokes equations; electrically conducted fluid flows; phase separation modeled by the Cahn-Hilliard equations; and deterministic or stochastic semi-linear heat equations arising in biology, chemistry, and population dynamics modeling. The text provides answers to the following problems, which are of great practical importance: Designing the feedback law using a minimal set of eigenfunctions of the linear operator obtained from the linearized equation around the target state Designing observers for the considered control systems Constructing time-discrete controllers requiring only partial knowledge of the state After reviewing standard notations and results in functional analysis, linear algebra, probability theory and PDEs, the author describes his novel stabilization algorithm. He then demonstrates how this abstract model can be applied to stabilization problems involving magnetohydrodynamic equations, stochastic PDEs, nonsteady-states, and more. Boundary Stabilization of Parabolic Equations will be of particular interest to researchers in control theory and engineers whose work involves systems control. Familiarity with linear algebra, operator theory, functional analysis, partial differential equations, and stochastic partial differential equations is required.

Modeling by Nonlinear Differential Equations - Paul Edgar Phillipson 2009

This book aims to provide mathematical analyses of nonlinear differential equations, which have proved pivotal to understanding many phenomena in physics, chemistry and biology. Topics of focus are autocatalysis and dynamics of molecular evolution, relaxation oscillations, deterministic chaos, reaction diffusion driven chemical pattern formation, solitons and neuron dynamics. Included is a discussion of processes from the viewpoints of reversibility, reflected by conservative classical mechanics, and irreversibility introduced by the dissipative role of diffusion. Each chapter presents the subject matter from the point of one or a few key equations, whose properties and consequences are amplified by approximate analytic solutions that are developed to support graphical display of exact computer solutions. Sample Chapter(s). Chapter 1: Theme and Contents of this Book (85 KB). Contents: Theme and Contents of this Book; Processes in closed and Open Systems; Dynamics of Molecular Evolution; Relaxation Oscillations; Order and Chaos; Reaction Diffusion Dynamics; Solitons; Neuron Pulse Propagation; Time Reversal, Dissipation and Conservation. Readership: Advanced undergraduates, graduate students and researchers in physics, chemistry, biology or bioinformatics who are interested in mathematical modeling.

Numerical Methods and Modeling for Chemical Engineers - Mark E. Davis 1984

An introduction to the quantitative treatment of differential equations arising from modeling physical phenomena in chemical engineering designed for advanced undergraduates or graduates of chemical engineering taking a course in applied mathematics. Presents up-to-date topics such as ODE-IVP's. Emphasizes numerical methods and modeling implemented in commercial mathematical software. Reviews and recommends which mathematical software to use. Examples included.

Mean Field Theories and Dual Variation - Mathematical Structures of the Mesoscopic Model - Takashi Suzuki 2015-11-19

Mean field approximation has been adopted to describe macroscopic phenomena from microscopic overviews. It is still in progress; fluid mechanics, gauge theory, plasma physics, quantum chemistry, mathematical oncology, non-equilibirum thermodynamics. spite of such a wide range of scientific areas that are concerned with the mean field theory, a unified study of its mathematical structure has not been discussed explicitly in the open literature. The benefit of this point of view on nonlinear problems should have significant impact on future research, as will be seen from the underlying features of self-assembly or bottom-up self-organization which is to be illustrated in a unified way. The aim of this book is to formulate the variational and hierarchical aspects of the equations that arise in the mean field theory from macroscopic profiles to microscopic principles, from dynamics to equilibrium, and from biological models to models that arise from chemistry and physics.

Generalized Characteristics of First Order PDEs - Arik Melikyan 1998-05-15

In some domains of mechanics, physics and control theory boundary value problems arise for nonlinear first order PDEs. A well-known classical result states a sufficiency condition for local existence and uniqueness of twice differentiable solution. This result is based on the method of characteristics (MC). Very often, and as a rule in control theory, the continuous nonsmooth (non-differentiable) functions have to be treated as a solutions to the PDE. At the points of smoothness such solutions satisfy the equation in classical sense. But if a function satisfies this condition only, with no requirements at the points of nonsmoothness, the PDE may have nonunique solutions. The uniqueness takes place if an appropriate matching principle for smooth solution branches defined in neighboring domains is applied or, in other words, the notion of generalized solution is considered. In each field an appropriate matching principle are used. In Optimal Control and Differential Games this principle is the optimality of the cost function. In physics and mechanics certain laws must be fulfilled for correct matching. A purely mathematical approach also can be used, when the generalized solution is introduced to obtain the existence and uniqueness of the solution, without being aimed to describe (to model) some particular physical phenomenon. Some formulations of the generalized solution may meet the modelling of a given phenomenon, the others may not.

Qualitative Analysis of Nonlinear Elliptic Partial Differential Equations - Vicenţiu D. Rădulescu 2008

This book provides a comprehensive introduction to the mathematical theory of nonlinear problems described by elliptic partial differential equations. These equations can be seen as nonlinear versions of the classical Laplace equation, and they appear as mathematical models in different branches of physics, chemistry, biology, genetics, and engineering and are also relevant in differential geometry and relativistic physics. Much of the modern theory of such equations is based on the calculus of variations and functional analysis. Concentrating on single-valued or multivalued elliptic equations with nonlinearities of various types, the aim of this volume is to obtain sharp existence or nonexistence results, as well as decay rates for general classes of solutions. Many technically relevant questions are presented and analyzed in detail. A systematic picture of the most relevant phenomena is obtained for the equations under study, including bifurcation, stability, asymptotic analysis, and optimal regularity of solutions. The method of presentation should appeal to readers with different backgrounds in functional analysis and nonlinear partial differential equations. All chapters include detailed heuristic arguments providing thorough motivation of the study developed later on in the text, in relationship with concrete processes arising in applied sciences. A systematic description of the most relevant singular phenomena described in this volume includes existence (or nonexistence) of solutions, unicity or multiplicity properties, bifurcation and asymptotic analysis, and optimal regularity. The book includes an extensive bibliography and a rich index, thus allowing for quick orientation among the vast collection of literature on the mathematical theory of nonlinear phenomena described by elliptic partial differential equations.

Mathematics of Complexity and Dynamical Systems - Robert A. Meyers 2011-10-05
Mathematics of Complexity and Dynamical Systems is an authoritative reference to the basic tools and concepts of complexity, systems theory, and dynamical systems from the perspective of pure and applied mathematics. Complex systems are systems that comprise many interacting parts with the ability to generate a new quality of collective behavior through self-organization, e.g. the spontaneous formation of temporal, spatial or functional structures. These systems are often characterized by extreme sensitivity to initial conditions as well as emergent behavior that are not readily predictable or even completely deterministic. The more than 100 entries in this wide-ranging, single source work provide a comprehensive explication of the theory and applications of mathematical complexity, covering ergodic theory, fractals and multifractals, dynamical systems, perturbation theory, solitons, systems and control theory, and related topics. Mathematics of Complexity and Dynamical Systems is an essential reference for all those interested in mathematical complexity, from undergraduate and graduate students up through professional researchers.

Stochastic Numerics for Mathematical Physics - Grigori N. Milstein 2021-12-03
This book is a substantially revised and expanded edition reflecting major developments in stochastic numerics since the first edition was published in 2004. The new topics, in particular, include mean-square and weak approximations in the case of nonglobally Lipschitz coefficients of Stochastic Differential Equations (SDEs) including the concept of rejecting trajectories; conditional probabilistic representations and their application to practical variance reduction using regression methods; multi-level Monte Carlo method; computing ergodic limits and additional classes of geometric integrators used in molecular dynamics; numerical methods for FBSDEs; approximation of parabolic SPDEs and nonlinear filtering problem based on the method of characteristics. SDEs have many applications in the natural sciences and in finance. Besides, the employment of probabilistic representations together with the Monte Carlo technique allows us to reduce the solution of multi-dimensional problems for partial differential equations to the integration of stochastic equations. This approach leads to powerful computational mathematics that is presented in the treatise. Many special schemes for SDEs are presented. In the second part of the book numerical methods for solving complicated problems for partial differential equations occurring in practical applications, both linear and nonlinear, are constructed. All the methods are presented with proofs and hence founded on rigorous reasoning, thus giving the book textbook potential. An overwhelming majority of the methods are accompanied by the corresponding numerical algorithms which are ready for implementation in practice. The book addresses researchers and graduate students in numerical analysis, applied probability, physics, chemistry, and engineering as well as mathematical biology and financial mathematics.

MEAN FIELD THEORIES AND DUAL VARIATION - Takashi Suzuki 2009-01-01
A mathematical theory is introduced in this book to unify a large class of nonlinear partial differential equation (PDE) models for better understanding and analysis of the physical and biological phenomena they represent. The so-called mean field approximation approach is adopted to describe the macroscopic phenomena from certain microscopic principles for this unified mathematical formulation. Two key ingredients for this approach are the notions of “duality” according to the PDE weak solutions and “hierarchy” for revealing the details of the otherwise hidden secrets, such as physical mystery hidden between particle density and field concentration, quantized blow up biological mechanism sealed in chemotaxis systems, as well as multi-scale mathematical explanations of the Smoluchowski–Poisson model in non-equilibrium thermodynamics, two-dimensional turbulence theory, self-dual gauge theory, and so forth. This book shows how and why many different nonlinear problems are inter-connected in terms of the properties of duality and scaling, and the way to analyze them mathematically.

Nonlinear PDEs: A Dynamical Systems Approach - Guido Schneider 2017-10-26
This is an introductory textbook about nonlinear dynamics of PDEs, with a focus on problems over unbounded domains and modulation equations. The presentation is example-oriented, and new mathematical tools are developed step by step, giving insight into some important classes of nonlinear PDEs and nonlinear dynamics phenomena which may occur in PDEs. The book consists of four parts. Parts I and II are introductions to finite- and infinite-dimensional dynamics defined by ODEs and by PDEs over bounded domains, respectively, including the basics of bifurcation and attractor theory. Part III introduces PDEs on the real line, including the Korteweg-de Vries equation, the Nonlinear Schrödinger equation and the Ginzburg-Landau equation. These examples often occur as simplest possible models, namely as amplitude or modulation equations, for some real world phenomena such as nonlinear waves and pattern formation. Part IV explores in more detail the connections between such complicated physical systems and the reduced models. For many models, a mathematically rigorous justification by approximation results is given. The parts of the book are kept as self-contained as possible. The book is suitable for self-study, and there are various possibilities to build one- or two-semester courses from the book.

Modeling By Nonlinear Differential Equations -

Reaction-Diffusion Automata: Phenomenology, Localisations, Computation - Andrew Adamatzky 2012-09-14
Reaction-diffusion and excitable media are amongst most intriguing substrates. Despite apparent simplicity of the physical processes involved the media exhibit a wide range of amazing patterns: from target and spiral waves to travelling localisations and stationary breathing patterns. These media are at the heart of most natural processes, including morphogenesis of living beings, geological formations, nervous and muscular activity, and socio-economic developments. This book explores a minimalist paradigm of studying reaction-diffusion and excitable media using locally-connected networks of finite-state machines: cellular automata and automata on proximity graphs. Cellular automata are marvellous objects per se because they show us how to generate and manage complexity using very simple rules of dynamical transitions. When combined with the reaction-diffusion paradigm the cellular automata become an essential user-friendly tool for modelling natural

systems and designing future and emergent computing architectures. The book brings together hot topics of non-linear sciences, complexity, and future and emergent computing. It shows how to discover propagating localisation and perform computation with them in very simple two-dimensional automaton models. Paradigms, models and implementations presented in the book strengthen the theoretical foundations in the area for future and emergent computing and lay key stones towards physical embodied information processing systems.
Differential Equation Analysis in Biomedical Science and Engineering - William E. Schiesser 2014-02-24
Features a solid foundation of mathematical and computational tools to formulate and solve real-world ODE problems across various fields With a step-by-step approach to solving ordinary differential equations (ODEs), Differential Equation Analysis in Biomedical Science and Engineering: Ordinary Differential Equation Applications with R successfully applies computational techniques for solving real-world ODE problems that are found in a variety of fields, including chemistry, physics, biology, and physiology. The book provides readers with the necessary knowledge to reproduce and extend the computed numerical solutions and is a valuable resource for dealing with a broad class of linear and nonlinear ordinary differential equations. The author's primary focus is on models expressed as systems of ODEs, which generally result by neglecting spatial effects so that the ODE dependent variables are uniform in space. Therefore, time is the independent variable in most applications of ODE systems. As such, the book emphasizes details of the numerical algorithms and how the solutions were computed. Featuring computer-based mathematical models for solving real-world problems in the biological and biomedical sciences and engineering, the book also includes: R routines to facilitate the immediate use of computation for solving differential equation problems without having to first learn the basic concepts of numerical analysis and programming for ODEs Models as systems of ODEs with explanations of the associated chemistry, physics, biology, and physiology as well as the algebraic equations used to calculate intermediate variables Numerical solutions of the presented model equations with a discussion of the important features of the solutions Aspects of general ODE computation through various biomolecular science and engineering applications Differential Equation Analysis in Biomedical Science and Engineering: Ordinary Differential Equation Applications with R is an excellent reference for researchers, scientists, clinicians, medical researchers, engineers, statisticians, epidemiologists, and pharmacokineticists who are interested in both clinical applications and interpretation of experimental data with mathematical models in order to efficiently solve the associated differential equations. The book is also useful as a textbook for graduate-level courses in mathematics, biomedical science and engineering, biology, biophysics, biochemistry, medicine, and engineering.
Singularly Perturbed Boundary-Value Problems - Luminita Barbu 2009-09-03
This book offers a detailed asymptotic analysis of some important classes of singularly perturbed boundary value problems which are mathematical models for phenomena in biology, chemistry, and engineering. The authors are particularly interested in nonlinear problems, which have gone little-examined so far in literature dedicated to singular perturbations. The treatment presented here combines successful results from functional analysis, singular perturbation theory, partial differential equations, and evolution equations.
Variational Methods - Michael Struwe 1996-01-01
Hilbert's talk at the second International Congress of 1900 in Paris marked the beginning of a new era in the calculus of variations. A development began which, within a few decades, brought tremendous success, highlighted by the 1929 theorem of Ljusternik and Schnirelman on the existence of three distinct prime closed geodesics on any compact surface of genus zero, and the 1930/31 solution of Plateau's problem by Douglas and Rad . The book gives a concise introduction to variational methods and presents an overview of areas of current research in this field. This new edition has been substantially enlarged, a new chapter on the Yamabe problem has been added and the references have been updated. All topics are illustrated by carefully chosen examples, representing the current state of the art in their field.
Solitons - Mohamed Atef Helal 2022-11-12
This newly updated volume of the Encyclopedia of Complexity and Systems Science (ECSS) presents several mathematical models that describe this physical phenomenon, including the famous non-linear equation Korteweg-de-Vries (KdV) that represents the canonical form of solitons. Also, there exists a class of nonlinear partial differential equations that led to solitons, e.g., Kadomtsev-Petviashvili (KP), Klein-Gordon (KG), Sine-Gordon (SG), Non-Linear Schrödinger (NLS), Korteweg-de-Vries Burger's (KdVB), etc. Different linear mathematical methods can be used to solve these models analytically, such as the Inverse Scattering Transformation (IST), Adomian Decomposition Method, Variational Iteration Method (VIM), Homotopy Analysis Method (HAM) and Homotopy Perturbation Method (HPM). Other non-analytic methods use the computational techniques available in such popular mathematical packages as Mathematica, Maple, and MATLAB. The main purpose of this volume is to provide physicists, engineers, and their students with the proper methods and tools to solve the soliton equations, and to discover the new possibilities of using solitons in multi-disciplinary areas ranging from telecommunications to biology, cosmology, and oceanographic studies.
Linear and Nonlinear Functional Analysis with Applications - Philippe G. Ciarlet 2013-10-10
This single-volume textbook covers the fundamentals of linear and nonlinear functional analysis, illustrating most of the basic theorems with numerous applications to linear and nonlinear partial differential equations and to selected topics from numerical analysis and optimization theory. This book has pedagogical appeal because it features self-contained and complete proofs of most of the theorems, some of which are not always easy to locate in the literature or are difficult to reconstitute. It also offers 401 problems and 52 figures, plus historical notes and many original references that provide an idea of the genesis of the important results, and it covers most of the core topics from functional analysis.
Singular Nonlinear Partial Differential Equations - Raymond Gérard 1996-01-01
The aim of this book is to put together all the results that are known about the existence of formal, holomorphic and singular solutions of singular non linear partial differential equations.
Non-linear Partial Differential Equations - Elemer E. Rosinger 1990
A massive transition of interest from solving linear partial differential equations to solving nonlinear ones has taken place during the last two or three decades. The availability of better computers has often made numerical experimentations progress faster than the theoretical understanding of nonlinear partial differential equations. The three most important nonlinear phenomena observed so far both experimentally and numerically, and studied theoretically in connection with such equations have been the solitons, shock waves and turbulence

or chaotical processes. In many ways, these phenomena have presented increasing difficulties in the mentioned order. In particular, the latter two phenomena necessarily lead to nonclassical or generalized solutions for nonlinear partial differential equations.

Modeling with Differential Equations in Chemical Engineering - Stanley M. Walas 1991

'Modelling with Differential Equations in Chemical Engineering' covers the modelling of rate processes of engineering in terms of differential equations. While it includes the purely mathematical aspects of the solution of differential equations, the main emphasis is on the derivation and solution of major equations of engineering and applied science. Methods of solving differential equations by analytical and numerical means are presented in detail with many solved examples, and problems for solution by the reader. Emphasis is placed on numerical and computer methods of solution. A key chapter in the book is devoted to the principles of mathematical modelling. These principles are applied to the equations in important engineering areas. The major disciplines covered are thermodynamics, diffusion and mass transfer, heat transfer, fluid dynamics, chemical reactions, and automatic control. These topics are of particular value to chemical engineers, but also are of interest to mechanical, civil, and environmental engineers, as well as applied scientists. The material is also suitable for undergraduate and beginning graduate students, as well as for review by practising engineers.