

An Introduction To The Fractional Calculus And Fractional Differential Equations

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General Fractional Derivatives World Scientific Publishing Company

Fractional calculus was first developed by pure mathematicians in the middle of the 19th century. Some 100 years later, engineers and physicists have found applications for these concepts in their areas. However there has traditionally been little interaction between these two communities. In particular, typical mathematical works provide extensive findings on aspects with comparatively little significance in applications, and the engineering literature often lacks mathematical detail and precision. This book bridges the gap between the two communities. It concentrates on the class of fractional derivatives most important in applications, the Caputo operators, and provides a self-contained, thorough and mathematically rigorous study of their properties and of the corresponding differential equations. The text is a useful tool for mathematicians and researchers from the applied sciences alike. It can also be used as a basis for teaching graduate courses on

fractional differential equations.

Fractional Differential Equations Springer Nature

Fractional calculus is undergoing rapidly and ongoing development. We can already recognize, that within its framework new concepts and strategies emerge, which lead to new challenging insights and surprising correlations between different branches of physics. This book is an invitation both to the interested student and the professional researcher. It presents a thorough introduction to the basics of fractional calculus and guides the reader directly to the current state-of-the-art physical interpretation. It is also devoted to the application of fractional calculus on physical problems, in the subjects of classical mechanics, friction, damping, oscillations, group theory, quantum mechanics, nuclear physics, and hadron spectroscopy up to quantum field theory.

Stochastic Models for Fractional Calculus An Introduction to the Fractional Calculus and Fractional Differential Equations

This book introduces a series of problems and methods insufficiently discussed in the field of Fractional Calculus – a major, emerging tool relevant to all areas of scientific inquiry. The authors present examples based on symbolic computation, written in Maple and Mathematica, and address

both mathematical and computational areas in the context of mathematical modeling and the generalization of classical integer-order methods. Distinct from most books, the present volume fills the gap between mathematics and computer fields, and the transition from integer- to fractional-order methods.

An Introduction for Physicists Academic Press

In the last two decades, fractional (or non integer) differentiation has played a very important role in various fields such as mechanics, electricity, chemistry, biology, economics, control theory and signal and image processing. For example, in the last three fields, some important considerations such as modelling, curve fitting, filtering, pattern recognition, edge detection, identification, stability, controllability, observability and robustness are now linked to long-range dependence phenomena. Similar progress has been made in other fields listed here. The scope of the book is thus to present the state of the art in the study of fractional systems and the application of fractional differentiation. As this volume covers recent applications of fractional calculus, it will be of interest to engineers, scientists, and applied mathematicians.

Fuzzy Fractional Differential Equations CRC Press

This work aims to present, in a systematic manner, results including the existence and uniqueness of solutions for the Cauchy Type and Cauchy problems involving nonlinear ordinary fractional differential equations.

Fractional Differential Equations CRC Press

This book introduces a series of problems and methods insufficiently discussed in the field of Fractional Calculus – a major, emerging tool relevant to all areas of scientific inquiry. The authors present examples based on symbolic computation, written in Maple and Mathematica, and address both mathematical and computational areas in the context of mathematical modeling and the generalization of classical integer-order methods. Distinct from most books, the present volume fills the gap between mathematics and computer fields, and the transition from integer- to fractional-order methods.

Springer Science & Business Media

Transmutations, Singular and Fractional Differential Equations with Applications to Mathematical Physics connects difficult problems with similar more simple ones. The book's strategy works for differential and integral equations and systems and for many theoretical and applied problems in mathematics, mathematical physics, probability and statistics, applied computer science and numerical methods. In addition to being exposed to recent advances, readers learn to use transmutation methods not only as practical tools, but also as vehicles that deliver theoretical insights. Presents the universal transmutation method as the most powerful for solving many problems in mathematics, mathematical physics, probability and statistics, applied computer science and numerical methods Combines mathematical rigor with an illuminating exposition full of historical notes and fascinating details Enables researchers, lecturers and students to find material under the single "roof"

Theoretical Developments and Applications in Physics and Engineering Springer Science & Business Media

The first derivative of a particle coordinate means its velocity, the second means its acceleration, but what does a fractional order derivative mean? Where does it come from, how does it work, where does it lead to? The two-volume book written on high didactic level answers these questions. Fractional Derivatives for Physicists and Engineers— The first volume contains a clear introduction into such a modern branch of analysis as the fractional calculus. The second develops a wide panorama of applications of the fractional calculus to various physical problems. This book recovers new perspectives in front of the reader dealing with turbulence and semiconductors, plasma and thermodynamics, mechanics and quantum optics, nanophysics and astrophysics. The book is addressed to students, engineers and physicists, specialists in theory of probability and statistics, in mathematical modeling and numerical simulations, to everybody who doesn't wish to stay apart from the new mathematical methods becoming more and more popular. Prof. Vladimir V. UCHAIKIN is a known Russian scientist and pedagogue, a Honored Worker of Russian High School, a member of the Russian Academy of Natural Sciences. He is the author of about three hundreds articles and more than a dozen books (mostly in Russian) in Cosmic ray physics, Mathematical physics, Levy stable statistics, Monte Carlo methods with applications to anomalous processes in complex systems of various levels: from quantum dots to the Milky Way galaxy.

An Application-Oriented Exposition Using Differential Operators of Caputo Type Springer Science & Business Media

This invaluable book provides a broad introduction to the fascinating and beautiful subject of Fractional Calculus of Variations (FCV). In 1996, FVC evolved in order to better describe non-conservative systems in mechanics. The inclusion of non-conservatism is extremely important from the point of view of applications. Forces that do not store energy are always present in real systems. They remove energy from the systems and, as a consequence, Noether's conservation laws cease to be valid. However, it is still possible to obtain the validity of Noether's principle using FCV. The new theory provides a more realistic approach to physics, allowing us to consider non-conservative systems in a natural way. The authors prove the necessary Euler-Lagrange conditions and corresponding Noether theorems for several types of fractional variational problems, with and without constraints, using Lagrangian and Hamiltonian formalisms. Sufficient optimality conditions are also obtained under convexity, and Leitmann's direct method is discussed within the framework of FCV. The book is self-contained and unified in presentation. It may be used as an advanced textbook by graduate students and ambitious undergraduates in mathematics and mechanics. It provides an opportunity for an introduction to FCV for experienced researchers. The explanations in the book are detailed, in order to capture the interest of the curious reader, and

the book provides the necessary background material required to go further into the subject and explore the rich research literature.

An Introduction for Physicists World Scientific

This book is a landmark title in the continuous move from integer to non-integer in mathematics: from integer numbers to real numbers, from factorials to the gamma function, from integer-order models to models of an arbitrary order. For historical reasons, the word 'fractional' is used instead of the word 'arbitrary'. This book is written for readers who are new to the fields of fractional derivatives and fractional-order mathematical models, and feel that they need them for developing more adequate mathematical models. In this book, not only applied scientists, but also pure mathematicians will find fresh motivation for developing new methods and approaches in their fields of research. A reader will find in this book everything necessary for the initial study and immediate application of fractional derivatives fractional differential equations, including several necessary special functions, basic theory of fractional differentiation, uniqueness and existence theorems, analytical numerical methods of solution of fractional differential equations, and many inspiring examples of applications. A unique survey of many applications of fractional calculus Presents basic theory Includes a unified presentation of selected classical results, which are important for applications Provides many examples Contains a separate chapter of fractional order control systems, which opens new perspectives in control theory The first systematic consideration of Caputo's fractional derivative in comparison with other selected approaches Includes tables of fractional derivatives, which can be used for evaluation of all considered types of fractional derivatives

A Theoretical Introduction World Scientific

This book aims to establish a foundation for fractional derivatives and fractional differential equations. The theory of fractional derivatives enables considering any positive order of differentiation. The history of research in this field is very long, with its origins dating back to Leibniz. Since then, many great mathematicians, such as Abel, have made contributions that cover not only theoretical aspects but also physical applications of fractional calculus. The fractional partial differential equations govern phenomena depending both on spatial and time variables and require more subtle treatments. Moreover, fractional partial differential equations are highly demanded model equations for solving real-world problems such as the anomalous diffusion in heterogeneous media. The studies of fractional partial differential equations have continued to expand explosively. However we observe that available mathematical theory for fractional partial differential equations is not still complete. In particular, operator-theoretical approaches are indispensable for some generalized categories of solutions such as weak solutions, but feasible operator-theoretic foundations for wide applications are not available in monographs. To make this monograph more readable, we are restricting it to a few fundamental types of time-fractional partial differential equations, forgoing many other important and exciting topics such as stability for nonlinear problems. However, we believe that this book works well as an introduction to mathematical research in such vast fields.

An Introduction to Fractional Mechanics Springer Nature

This monograph provides a comprehensive overview of the author's work on the fields of fractional calculus and waves in linear viscoelastic media, which includes his pioneering contributions on the applications of special functions of the Mittag-Leffler and Wright types. It is intended to serve as a general introduction to the above-mentioned areas of mathematical modeling. The explanations in the book are detailed enough to capture the interest of the curious reader, and complete enough to provide the necessary background material needed to delve further into the subject and explore the research literature given in the huge general bibliography. This book is likely to be of interest to applied scientists and engineers. Contents:Essentials of Fractional CalculusEssentials of Linear ViscoelasticityFractional Viscoelastic ModelsWaves in Linear Viscoelastic Media: Dispersion and DissipationWaves in Linear Viscoelastic Media: Asymptotic RepresentationsDiffusion and Wave-Propagation via Fractional CalculusAppendices:The Eulerian FunctionsThe Bessel FunctionsThe Error FunctionsThe Exponential Integral FunctionsThe Mittag-Leffler FunctionsThe Wright Functions Readership: Graduate and PhD students in applied mathematics, classical physics, mechanical engineering and chemical physics; academic institutions; research centers. Keywords:Fractional Calculus;Fractional Derivatives;Fractional Integrals;Linear Viscoelasticity;Rheological Models;Special Functions;Mittag-Leffler Functions;Wright Functions;Integral Transforms;Laplace Transforms;Fourier

Transforms;Waves;Dispersion;Dissipation;Diffusion;Anomalous DiffusionKey Features:Contains

accessible mathematical language for easy understandingFeatures ample examples to reiterate concepts in the bookMakes extensive use of graphical imagesIncludes a large and informative general bibliography for further research

Introduction to Fractional Differential Equations John Wiley & Sons

Numerical Methods for Fractional Calculus presents numerical methods for fractional integrals and fractional derivatives, finite difference methods for fractional ordinary differential equations (FODEs) and fractional partial differential equations (FPDEs), and finite element methods for FPDEs.The book introduces the basic definitions and properties

An Introduction to Mathematical Models Academic Press

In this book the author presents the Opial, Poincaré, Sobolev, Hilbert, and Ostrowski fractional differentiation inequalities. Results for the above are derived using three different types of fractional derivatives, namely by Canavati, Riemann-Liouville and Caputo. The univariate and multivariate cases are both examined. Each chapter is self-contained. The theory is presented systematically along with the applications. The application to information theory is also examined. This monograph is suitable for researchers and graduate students in pure mathematics. Applied mathematicians, engineers, and other applied scientists will also find this book useful.

Fractional Order Analysis Elsevier

This book is not a text devoted to a pedagogical presentation of a specialized topic nor is it a monograph focused on the author's area of research. It accomplishes both these things while providing a rationale for why the reader ought to be interested in learning about fractional calculus. This book is for researchers who have heard about many

An Introduction to Fractional Derivatives, Fractional Differential Equations, to Methods of Their Solution and Some of Their Applications Elsevier

Fractional calculus is a collection of relatively little-known mathematical results concerning generalizations of differentiation and integration to noninteger orders. While these results have been accumulated over centuries in various branches of mathematics, they have until recently found little appreciation or application in physics and other mathematically oriented sciences. This situation is beginning to change, and there are now a growing number of research areas in physics which employ fractional calculus. This volume provides an introduction to fractional calculus for physicists, and collects easily accessible review articles surveying those areas of physics in which applications of fractional calculus have recently become prominent. Contents:An Introduction to Fractional Calculus (P L Butzer & U Westphal)Fractional Time Evolution (R Hilfer)Fractional Powers of Infinitesimal Generators of Semigroups (U Westphal)Fractional Differences, Derivatives and Fractal Time Series (B J West & P Grigolini)Fractional Kinetics of Hamiltonian Chaotic Systems (G M Zaslavsky)Polymer Science Applications of Path-Integration, Integral Equations, and Fractional Calculus (J F Douglas)Applications to Problems in Polymer Physics and Rheology (H Schiessel et al.)Applications of Fractional Calculus Techniques to Problems in Biophysics (T F Nonnenmacher & R Metzler)Fractional Calculus and Regular Variation in Thermodynamics (R Hilfer) Readership: Statistical, theoretical and mathematical physicists. Keywords:Fractional Calculus in PhysicsReviews: "This monograph provides a systematic treatment of the theory and applications of fractional calculus for physicists. It contains nine review articles surveying those areas in which fractional calculus has become important. All the chapters are self-contained." Mathematics Abstracts

Local Fractional Integral Transforms and Their Applications Springer Nature

When a new extraordinary and outstanding theory is stated, it has to face criticism and skepticism, because it is beyond the usual concept. The fractional calculus though not new, was not discussed or developed for a long time, particularly for lack of its application to real life problems. It is extraordinary because it does not deal with 'ordinary' differential calculus. It is outstanding because it can now be applied to situations where existing theories fail to give satisfactory results. In this book not only mathematical abstractions are discussed in a lucid manner, with physical mathematical and geometrical explanations, but also several practical applications are given particularly for system identification, description and then efficient controls. The normal physical laws like, transport theory, electrodynamics, equation of motions, elasticity, viscosity, and several others of are based on 'ordinary' calculus. In this book these physical laws are generalized in fractional calculus contexts; taking, heterogeneity effect in transport background, the space having traps or islands, irregular distribution of charges, non-ideal spring with mass connected to a pointless-mass ball, material behaving with viscous as well as elastic properties, system relaxation with and without memory, physics of random delay in computer network; and several others;

mapping the reality of nature closely. The concept of fractional and complex order differentiation and integration are elaborated mathematically, physically and geometrically with examples. The practical utility of local fractional differentiation for enhancing the character of singularity at phase transition or characterizing the irregularity measure of response function is deliberated. Practical results of viscoelastic experiments, fractional order controls experiments, design of fractional controller and practical circuit synthesis for fractional order elements are elaborated in this book. The book also maps theory of classical integer order differential equations to fractional calculus contexts, and deals in details with conflicting and demanding initialization issues, required in classical techniques. The book presents a modern approach to solve the 'solvable' system of fractional and other differential equations, linear, non-linear; without perturbation or transformations, but by applying physical principle of action-and-opposite-reaction, giving 'approximately exact' series solutions. Historically, Sir Isaac Newton and Gottfried Wilhelm Leibniz independently discovered calculus in the middle of the 17th century. In recognition to this remarkable discovery, J.von Neumann remarked, "...the calculus was the first achievement of modern mathematics and it is difficult to overestimate its importance. I think it defines more equivocally than anything else the inception of modern mathematical analysis which is logical development, still constitute the greatest technical advance in exact thinking." This XXI century has thus started to 'think-exactly' for advancement in science & technology by growing application of fractional calculus, and this century has started speaking the language which nature understands the best.

Fractional Differentiation Inequalities Springer

General Fractional Derivatives: Theory, Methods and Applications provides knowledge of the special functions with respect to another function, and the integro-differential operators where the integrals are of the convolution type and exist the singular, weakly singular and nonsingular

kernels, which exhibit the fractional derivatives, fractional integrals, general fractional derivatives, and general fractional integrals of the constant and variable order without and with respect to another function due to the appearance of the power-law and complex herbivores to figure out the modern developments in theoretical and applied science. Features: Give some new results for fractional calculus of constant and variable orders. Discuss some new definitions for fractional calculus with respect to another function. Provide definitions for general fractional calculus of constant and variable orders. Report new results of general fractional calculus with respect to another function. Propose news special functions with respect to another function and their applications. Present new models for the anomalous relaxation and rheological behaviors. This book serves as a reference book and textbook for scientists and engineers in the fields of mathematics, physics, chemistry and engineering, senior undergraduate and graduate students. Dr. Xiao-Jun Yang is a full professor of Applied Mathematics and Mechanics, at China University of Mining and Technology, China. He is currently an editor of several scientific journals, such as Fractals, Applied Numerical Mathematics, Mathematical Modelling and Analysis, International Journal of Numerical Methods for Heat & Fluid Flow, and Thermal Science.

Theory, Methods and Applications Elsevier

Fractional calculus is a rapidly growing field of research, at the interface between probability, differential equations, and mathematical physics. It is used to model anomalous diffusion, in which a cloud of particles spreads in a different manner than traditional diffusion. This monograph develops the basic theory of fractional calculus and anomalous diffusion, from the point of view of probability. In this book, we will see how fractional calculus and anomalous diffusion can be understood at a deep and intuitive level, using ideas from probability. It covers basic limit theorems for random variables and random vectors with heavy tails. This includes regular

variation, triangular arrays, infinitely divisible laws, random walks, and stochastic process convergence in the Skorokhod topology. The basic ideas of fractional calculus and anomalous diffusion are closely connected with heavy tail limit theorems. Heavy tails are applied in finance, insurance, physics, geophysics, cell biology, ecology, medicine, and computer engineering. The goal of this book is to prepare graduate students in probability for research in the area of fractional calculus, anomalous diffusion, and heavy tails. Many interesting problems in this area remain open. This book will guide the motivated reader to understand the essential background needed to read and understand current research papers, and to gain the insights and techniques needed to begin making their own contributions to this rapidly growing field.

An Approach Via Fractional Derivatives Springer

In this book, we study theoretical and practical aspects of computing methods for mathematical modelling of nonlinear systems. A number of computing techniques are considered, such as methods of operator approximation with any given accuracy; operator interpolation techniques including a non-Lagrange interpolation; methods of system representation subject to constraints associated with concepts of causality, memory and stationarity; methods of system representation with an accuracy that is the best within a given class of models; methods of covariance matrix estimation; methods for low-rank matrix approximations; hybrid methods based on a combination of iterative procedures and best operator approximation; and methods for information compression and filtering under condition that a filter model should satisfy restrictions associated with causality and different types of memory. As a result, the book represents a blend of new methods in general computational analysis, and specific, but also generic, techniques for study of systems theory and its particular branches, such as optimal filtering and information compression. - Best operator approximation, - Non-Lagrange interpolation, - Generic Karhunen-Loeve transform - Generalised low-rank matrix approximation - Optimal data compression - Optimal nonlinear filtering

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