

**A P P L I C A T I O N S**  
**OF**  
**FRACTIONAL CALCULUS**  
**IN PHYSICS**

**Editor**  
**R. Hilfer**

**World Scientific**

# Applications Of Fractional Calculus In Physics

**Sachin Bhalekar**



## **Applications Of Fractional Calculus In Physics:**

*Applications Of Fractional Calculus In Physics* Rudolf Hilfer, 2000-03-02 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 **Advances in Fractional Calculus** J.

Sabatier, O. P. Agrawal, J. A. Tenreiro Machado, 2007-07-28 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 **Fractional Dynamics** Vasily E. Tarasov, 2011-01-04 Fractional Dynamics Applications of Fractional

Calculus to Dynamics of Particles Fields and Media presents applications of fractional calculus integral and differential equations of non integer orders in describing systems with long time memory non local spatial and fractal properties Mathematical models of fractal media and distributions generalized dynamical systems and discrete maps non local statistical mechanics and kinetics dynamics of open quantum systems the hydrodynamics and electrodynamics of complex media with non local properties and memory are considered This book is intended to meet the needs of scientists and graduate students in physics mechanics and applied mathematics who are interested in electrodynamics statistical and condensed matter physics quantum dynamics complex media theories and kinetics discrete maps and lattice models and nonlinear dynamics and chaos Dr Vasily E Tarasov is a Senior Research Associate at Nuclear Physics Institute of Moscow State University and an Associate Professor at Applied Mathematics and Physics Department of Moscow Aviation Institute

Fractional Calculus and its Applications in Physics Dumitru Baleanu, Devendra Kumar, 2019-11-15 *Applications of Fractional Calculus to Modeling in Dynamics and Chaos* J. F. Gómez-Aguilar, Abdon Atangana, 2022-09-29 Applications of Fractional Calculus to Modeling in Dynamics and Chaos aims to present novel developments trends and applications of fractional order derivatives with power law and Mittag Leffler kernel in the areas of chemistry mechanics chaos epidemiology fluid mechanics modeling and engineering Non singular and non local fractional order derivatives have been applied in

different chapters to describe complex problems The book offers theory and practical applications for the solutions of real life problems and will be of interest to graduate level students educators researchers and scientists interested in mathematical modeling and its diverse applications Features Discusses real world problems theory and applications Covers new developments and advances in the various areas of nonlinear dynamics signal processing and chaos Suitable to teach master s and or PhD level graduate students and can be used by researchers from any field of the social health and physical sciences

**Fractional Calculus: An Introduction For Physicists (2nd Edition)** Richard Herrmann,2014-01-03 The book presents a concise introduction to the basic methods and strategies in fractional calculus and enables the reader to catch up with the state of the art in this field as well as to participate and contribute in the development of this exciting research area The contents are devoted to the application of fractional calculus to physical problems The fractional concept is applied to subjects in classical mechanics group theory quantum mechanics nuclear physics hadron spectroscopy and quantum field theory and it will surprise the reader with new intriguing insights This new extended edition now also covers additional chapters about image processing folded potentials in cluster physics infrared spectroscopy and local aspects of fractional calculus A new feature is exercises with elaborated solutions which significantly supports a deeper understanding of general aspects of the theory As a result this book should also be useful as a supporting medium for teachers and courses devoted to this subject

**Fractional Derivative Modeling in Mechanics and Engineering** Wen Chen,HongGuang Sun,Xicheng Li,2022-02-26 This textbook highlights the theory of fractional calculus and its wide applications in mechanics and engineering It describes in details the research findings in using fractional calculus methods for modeling and numerical simulation of complex mechanical behavior It covers the mathematical basis of fractional calculus the relationship between fractal and fractional calculus unconventional statistics and anomalous diffusion typical applications of fractional calculus and the numerical solution of the fractional differential equation It also includes latest findings such as variable order derivative distributed order derivative and its applications Different from other textbooks in this subject the book avoids lengthy mathematical demonstrations and presents the theories in close connection to the applications in an easily readable manner This textbook is intended for students researchers and professionals in applied physics engineering mechanics and applied mathematics It is also of high reference value for those in environmental mechanics geotechnical mechanics biomechanics and rheology

**Recent Trends in Fractional Calculus and Its Applications** Praveen Agarwal,Luis Vázquez Martínez,Ervin K. Lenzi,2024-07-02 Recent Trends in Fractional Calculus and Its Applications addresses the answer to this very basic question Why is Fractional Calculus important Until recent times Fractional Calculus was considered as a rather esoteric mathematical theory without applications but in the last few decades there has been an explosion of research activities on the application of Fractional Calculus to very diverse scientific fields ranging from the physics of diffusion and advection phenomena to control systems to finance and economics An important part of mathematical modelling of objects

and processes is a description of their dynamics The term Fractional Calculus is more than 300 years old It is a generalization of the ordinary differentiation and integration to noninteger arbitrary order The subject is as old as the calculus of differentiation and goes back to times when Leibniz Gauss and Newton invented this kind of calculation Several mathematicians contributed to this subject over the years People like Liouville Riemann and Weyl made major contributions to the theory of Fractional Calculus In recent decades the field of Fractional Calculus has attracted the interest of researchers in several areas including mathematics physics chemistry engineering finance and social sciences Provides the most recent and up to date developments in the Fractional Calculus and its application areas Presents pre preparation ideas to help researchers scientists clinicians face the new challenges in the application of fractional differential equations Helps researchers and scientists understand the importance of the Fractional Calculus to solve many problems in Biomedical Engineering and applied sciences

*Fractional Dynamics* Vasilij E. Tarasov, 2010

*Fractional Calculus: An Introduction For Physicists (Third Edition)* Richard Herrmann, 2018-07-09 The third edition of this book is designed to carefully and coherently introduce fractional calculus to physicists by applying the ideas to two distinct applications classical problems and multi particle quantum problems There remain many open questions and the field remains an active area of research Dr Herrmann s book is an excellent introduction to this field of study Contemporary Physics The book presents a concise introduction to the basic methods and strategies in fractional calculus which enables the reader to catch up with the state of the art in this field and to participate and contribute in the development of this exciting research area This book is devoted to the application of fractional calculus on physical problems The fractional concept is applied to subjects in classical mechanics image processing folded potentials in cluster physics infrared spectroscopy group theory quantum mechanics nuclear physics hadron spectroscopy up to quantum field theory and will surprise the reader with new intriguing insights This new extended edition includes additional chapters about numerical solution of the fractional Schrödinger equation self similarity and the geometric interpretation of non isotropic fractional differential operators Motivated by the positive response new exercises with elaborated solutions are added which significantly support a deeper understanding of the general aspects of the theory Besides students as well as researchers in this field this book will also be useful as a supporting medium for teachers teaching courses devoted to this subject

**Frontiers in Fractional Calculus** Sachin Bhalekar, 2018-03-21 This book brings together eleven topics on different aspects of fractional calculus in a single volume It provides readers the basic knowledge of fractional calculus and introduces advanced topics and applications The information in the book is presented in four parts 1 Fractional Diffusion Equations i solutions of fractional diffusion equations using wavelet methods ii the maximum principle for time fractional diffusion equations iii nonlinear sub diffusion equations 2 Mathematical Analysis i shifted Jacobi polynomials for solving and identifying coupled fractional delay differential equations ii the monotone iteration principle in the theory of Hadamard fractional delay differential equations iii dynamics of fractional order modified Bhalekar Gejji System

iv Grunwald Letnikov derivatives 3 Computational Techniques GPU computing of special mathematical functions used in fractional calculus 4 Reviews i the popular iterative method NIM ii fractional derivative with non singular kernels iii some open problems in fractional order nonlinear system This is a useful reference for researchers and graduate level mathematics students seeking knowledge about of fractional calculus and applied mathematics      **Recent Advances in Nonlinear**

**Dynamics and Synchronization** Kyandoghere Kyamakya, Herwig Unger, Jean Chamberlain Chedjou, Nikolai F. Rulkov, Zhong Li, 2009-09-30 In essence the dynamics of real world systems i e engineered systems natural systems social systems etc is nonlinear The analysis of this nonlinear character is generally performed through both observational and modeling processes aiming at deriving appropriate models mathematical logical graphical etc to simulate or mimic the spatiotemporal dynamics of the given systems The complex intrinsic nature of these systems i e nonlinearity and spatiotemporal dynamics can lead to striking dynamical behaviors such as regular or irregular stable or unstable periodicity or multi periodicity torus or chaotic dynamics The various potential applications of the knowledge about such dynamics in technical sciences engineering are being intensively demonstrated by diverse ongoing research activities worldwide However both the modeling and the control of the nonlinear dynamics in a range of systems is still not yet well understood e g system models with time varying coefficients immune systems swarm intelligent systems chaotic and fractal systems stochastic systems self organized systems etc This is due amongst others to the challenging task of establishing a precise and systematic fundamental or theoretical framework e g methods and tools to analyze understand explain and predict the nonlinear dynamical behavior of these systems in some cases even in real time The full insight in systems nonlinear dynamic behavior is generally achieved through approaches involving analytical numerical and or experimental methods      **Functional Fractional Calculus** Shantanu

Das, 2011-06-01 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

Integral Methods in Science and Engineering Christian Constanda, Bardo E.J. Bodmann, Haroldo F. de Campos Velho, 2013-08-13 Advances in science and technology are driven by the development of rigorous mathematical foundations for the study of both theoretical and experimental models With certain methodological variations this type of study always comes down to the application of analytic or computational integration procedures making such tools indispensable With a wealth of cutting edge research in the field Integral Methods in Science and Engineering Progress in Numerical and Analytic Techniques provides a detailed portrait of both the construction of theoretical integral techniques and their application to specific problems in science and engineering The chapters in this volume are based on talks given by well known researchers at the Twelfth International Conference on Integral Methods in Science and Engineering July 23-27 2012 in Porto Alegre Brazil They address a broad range of topics from problems of existence and uniqueness for singular integral equations on domain boundaries to numerical integration via finite and boundary elements conservation laws hybrid methods and other quadrature related approaches The contributing authors bring their expertise to bear on a number of topical problems that have to date resisted solution thereby offering help and guidance to fellow professionals worldwide Integral Methods in Science and Engineering Progress in Numerical and Analytic Techniques will be a valuable resource for researchers in applied mathematics physics and mechanical and electrical engineering for graduate students in these disciplines and for various other professionals who use integration as an essential tool in their work

**Solved Exercises in Fractional Calculus** Edmundo Capelas de Oliveira, 2019-05-31 This book contains a brief historical introduction and state of the art in fractional calculus The author introduces some of the so called

special functions in particular those which will be directly involved in calculations The concepts of fractional integral and fractional derivative are also presented Each chapter except for the first one contains a list of exercises containing suggestions for solving them and at last the resolution itself At the end of those chapters there is a list of complementary exercises The last chapter presents several applications of fractional calculus

**Applications in Physics, Part B** Vasily E. Tarasov, 2019-02-19 This multi volume handbook is the most up to date and comprehensive reference work in the field of fractional calculus and its numerous applications This fifth volume collects authoritative chapters covering several applications of fractional calculus in physics including electrodynamics statistical physics and physical kinetics and quantum theory

**Advances in Differential and Difference Equations with Applications 2020** Dumitru Baleanu, 2021-01-20 It is very well known that differential equations are related with the rise of physical science in the last several decades and they are used successfully for models of real world problems in a variety of fields from several disciplines Additionally difference equations represent the discrete analogues of differential equations These types of equations started to be used intensively during the last several years for their multiple applications particularly in complex chaotic behavior A certain class of differential and related difference equations is represented by their respective fractional forms which have been utilized to better describe non local phenomena appearing in all branches of science and engineering The purpose of this book is to present some common results given by mathematicians together with physicists engineers as well as other scientists for whom differential and difference equations are valuable research tools The reported results can be used by researchers and academics working in both pure and applied differential equations

**Mathematical Analysis and Applications** Themistocles M. Rassias, Panos M. Pardalos, 2019-12-12 An international community of experts scientists comprise the research and survey contributions in this volume which covers a broad spectrum of areas in which analysis plays a central role Contributions discuss theory and problems in real and complex analysis functional analysis approximation theory operator theory analytic inequalities the Radon transform nonlinear analysis and various applications of interdisciplinary research some are also devoted to specific applications such as the three body problem finite element analysis in fluid mechanics algorithms for difference of monotone operators a vibrational approach to a financial problem and more This volume is useful to graduate students and researchers working in mathematics physics engineering and economics

**Advances in Non-Integer Order Calculus and Its Applications** Agnieszka B. Malinowska, Dorota Mozyrska, Łukasz Sajewski, 2019-04-17 This book provides an overview of some recent findings in the theory and applications of non integer order systems Discussing topics ranging from the mathematical foundations to technical applications of continuous time and discrete time fractional calculus it includes 22 original research papers and is subdivided into four parts Mathematical Foundations Approximation Modeling and Simulations Fractional Systems Analysis and Control Applications The papers were selected from those presented at the 10th International Conference of Non integer Order Calculus and its Applications which



was held at the Bialystok University of Technology Poland September 20 21 2018 Thanks to the broad spectrum of topics covered the book is suitable for researchers from applied mathematics and engineering It is also a valuable resource for graduate students as well as for scholars looking for new mathematical tools

**Emerging Applications of Differential Equations and Game Theory** Alparslan Gök, S?rma Zeynep, Aru?aslan Çinçin, Duygu, 2019-11-22 Branches of mathematics and advanced mathematical algorithms can help solve daily problems throughout various fields of applied sciences Domains like economics mechanical engineering and multi person decision making benefit from the inclusion of mathematics to maximize utility and cooperation across disciplines There is a need for studies seeking to understand the theories and practice of using differential mathematics to increase efficiency and order in the modern world Emerging Applications of Differential Equations and Game Theory is a collection of innovative research that examines the recent advancements on interdisciplinary areas of applied mathematics While highlighting topics such as artificial neuron networks stochastic optimization and dynamical systems this publication is ideally designed for engineers cryptologists economists computer scientists business managers mathematicians mechanics academicians researchers and students

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