

Nonlinear Oscillations Dynamical Systems And Bifurcations

This textbook is aimed at newcomers to nonlinear dynamics and chaos, especially students taking a first course in the subject. The presentation stresses analytical methods, concrete examples, and geometric intuition. The theory is developed systematically, starting with first-order differential equations and their bifurcations, followed by phase plane analysis, limit cycles and their bifurcations, and culminating with the Lorenz equations, chaos, iterated maps, period doubling, renormalization, fractals, and strange attractors.

This book deals with the bifurcation and chaotic aspects of damped and driven nonlinear oscillators. The analytical and numerical aspects of the chaotic dynamics of these oscillators are covered, together with appropriate experimental studies using nonlinear electronic circuits. Recent exciting developments in chaos research are also discussed, such as the control and synchronization of chaos and possible technological applications.

Nonlinear Oscillations, Dynamical Systems, and Bifurcations of Vector Fields Springer
Many partial differential equations (PDEs) that arise in physics can be viewed as infinite-dimensional Hamiltonian systems. This monograph presents recent existence results of nonlinear oscillations of Hamiltonian PDEs, particularly of periodic solutions for completely resonant nonlinear wave equations. The text serves as an introduction to research in this fascinating and rapidly growing field. Graduate students and researchers interested in variational techniques and nonlinear analysis applied to Hamiltonian PDEs will find inspiration in the book.

Over the last four decades there has been extensive development in the theory of dynamical systems. This book aims at a wide audience where the first four chapters have been used for an undergraduate course in Dynamical Systems. Material from the last two chapters and from the appendices has been used quite a lot for master and PhD courses. All chapters are concluded by an exercise section. The book is also directed towards researchers, where one of the challenges is to help applied researchers acquire background for a better understanding of the data that computer simulation or experiment may provide them with the development of the theory.

Non-Linear Differential Equations and Dynamical Systems is the second book within Ordinary Differential Equations with Applications to Trajectories and Vibrations, Six-volume Set. As a set, they are the fourth volume in the series Mathematics and Physics Applied to Science and Technology. This second book consists of two chapters (chapters 3 and 4 of the set). The first chapter considers non-linear differential equations of first order, including variable coefficients. A first-order differential equation is equivalent to a first-order differential in two variables. The differentials of order higher than the first and with more than two variables are also considered. The applications include the representation of vector fields by potentials. The second chapter in the book starts with linear oscillators with coefficients varying with time, including parametric resonance. It proceeds to non-linear oscillators including non-linear resonance, amplitude jumps, and hysteresis. The non-linear restoring and friction forces also apply to electromechanical dynamos. These are examples of dynamical systems with bifurcations that may lead to chaotic motions. Presents general first-order differential equations including non-linear like the Riccati equation Discusses differentials of the first or higher order in two or more variables Includes discretization of differential equations as finite difference equations Describes parametric resonance of linear time dependent oscillators specified by the Mathieu functions and other methods Examines non-linear oscillations and damping of dynamical systems including bifurcations and chaotic motions

Dynamical systems and Nonlinear Waves in Plasmas is written in a clear and

comprehensible style to serve as a compact volume for advanced postgraduate students and researchers working in the areas of Applied Physics, Applied Mathematics, Dynamical Systems, Nonlinear waves in Plasmas or other nonlinear media. It provides an introduction to the background of dynamical systems, waves, oscillations and plasmas. Basic concepts of dynamical systems and phase plane analysis for the study of dynamical properties of nonlinear waves in plasmas are presented. Different kinds of waves in plasmas are introduced. Reductive perturbative technique and its applications to derive different kinds of nonlinear evolution equations in plasmas are discussed. Analytical wave solutions of these nonlinear evolution equations are presented using the concept of bifurcation theory of planar dynamical systems in a very simple way. Bifurcations of both small and arbitrary amplitudes of various nonlinear acoustic waves in plasmas are presented using phase plots and time-series plots. Super nonlinear waves and its bifurcation behaviour are discussed for various plasma systems. Multiperiodic, quasiperiodic and chaotic motions of nonlinear plasma waves are discussed in presence of external periodic force. Multistability of plasma waves is investigated. Stable oscillation of plasma waves is also presented in dissipative plasmas. The book is meant for undergraduate and postgraduate students studying plasma physics. It will also serve a reference to the researchers, scientists and faculties to pursue the dynamics of nonlinear waves and its properties in plasmas. It describes the concept of dynamical systems and is useful in understanding exciting features, such as solitary wave, periodic wave, supernonlinear wave, chaotic, quasiperiodic and coexisting structures of nonlinear waves in plasmas. The concepts and approaches, discussed in the book, will also help the students and professionals to study such features in other nonlinear media.

Many dynamical systems are described by differential equations that can be separated into one part, containing linear terms with constant coefficients, and a second part, relatively small compared with the first, containing nonlinear terms. Such a system is said to be weakly nonlinear. The small terms rendering the system nonlinear are referred to as perturbations. A weakly nonlinear system is called quasi-linear and is governed by quasi-linear differential equations. We will be interested in systems that reduce to harmonic oscillators in the absence of perturbations. This book is devoted primarily to applied asymptotic methods in nonlinear oscillations which are associated with the names of N. M. Krylov, N. N. Bogoliubov and Yu. A. Mitropolskii. The advantages of the present methods are their simplicity, especially for computing higher approximations, and their applicability to a large class of quasi-linear problems. In this book, we confine ourselves basically to the scheme proposed by Krylov, Bogoliubov as stated in the monographs [6,211]. We use these methods, and also develop and improve them for solving new problems and new classes of nonlinear differential equations. Although these methods have many applications in Mechanics, Physics and Technique, we will illustrate them only with examples which clearly show their strength and which are themselves of great interest. A certain amount of more advanced material has also been included, making the book suitable for a senior elective or a beginning graduate course on nonlinear oscillations.

This book highlights the latest findings on nonlinear dynamical systems including two types of attractors: self-excited and hidden attractors. Further, it presents both theoretical and practical approaches to investigating nonlinear dynamical systems with

self-excited and hidden attractors. The book includes 20 chapters contributed by respected experts, which focus on various applications such as biological systems, memristor-based systems, fractional-order systems, finance systems, business cycles, oscillators, coupled systems, hyperchaotic systems, flexible robot manipulators, electronic circuits, and control models. Special attention is given to modeling, design, circuit realization, and practical applications to address recent research problems in nonlinear dynamical systems. The book provides a valuable reference guide to nonlinear dynamical systems for engineers, researchers, and graduate students, especially those whose work involves mechanics, electrical engineering, and control systems.

An application of the techniques of dynamical systems and bifurcation theories to the study of nonlinear oscillations. Taking their cue from Poincare, the authors stress the geometrical and topological properties of solutions of differential equations and iterated maps. Numerous exercises, some of which require nontrivial algebraic manipulations and computer work, convey the important analytical underpinnings of problems in dynamical systems and help readers develop an intuitive feel for the properties involved.

Providing readers with a solid basis in dynamical systems theory, as well as explicit procedures for application of general mathematical results to particular problems, the focus here is on efficient numerical implementations of the developed techniques. The book is designed for advanced undergraduates or graduates in applied mathematics, as well as for Ph.D. students and researchers in physics, biology, engineering, and economics who use dynamical systems as model tools in their studies. A moderate mathematical background is assumed, and, whenever possible, only elementary mathematical tools are used. This new edition preserves the structure of the first while updating the context to incorporate recent theoretical developments, in particular new and improved numerical methods for bifurcation analysis.

An introduction to nonlinear differential equations which equips undergraduate students with the know-how to appreciate stability theory and bifurcation.

We present an improved and enlarged version of our book *Nonlinear Dynamics of Chaotic and Stochastic Systems* published by Springer in 2002. Basically, the new edition of the book corresponds to its first version. While

preparing this edition we made some clarifications in several sections and also corrected the misprints noticed in some formulas. Besides, three new sections have been added to Chapter 2. They are "Statistical Properties of Dynamical Chaos," "Effects of Synchronization in Extended Self-Sustained Oscillatory Systems," and "Synchronization in Living Systems." The sections indicated reflect the most interesting results obtained by the authors after publication of the first edition. We hope that the new edition of the book will be of great interest for a wide section of readers who are already specialists or those who are beginning research in the fields of nonlinear oscillation and wave theory, dynamical chaos, synchronization, and stochastic process theory. Saratov, Berlin, and St. Louis V.S. Anishchenko November 2006 A.B. Neiman T.E. Vadiavasova V.V. Astakhov L. Schimansky-Geier Preface to the First Edition

This book is devoted to the classical background and to contemporary results on nonlinear dynamics of deterministic and stochastic systems. Considerable attention is given to the effect of noise on various regimes of dynamic systems with noise-induced order. On the one hand, there exists a rich literature of excellent books on nonlinear dynamics and chaos; on the other hand, there are many marvelous monographs and textbooks on the statistical physics of far-from-equilibrium

and stochastic processes. This book is an attempt to combine the approach of nonlinear dynamics based on the deterministic evolution equations with the approach of statistical physics based on stochastic or kinetic equations. One of our main aims is to show the important role of noise in the organization and properties of dynamic regimes of nonlinear dissipative systems. This book introduces the mathematical properties of nonlinear systems, mostly difference and differential equations, as an integrated theory, rather than presenting isolated fashionable topics.

A systematic outline of the basic theory of oscillations, combining several tools in a single textbook. The author explains fundamental ideas and methods, while equally aiming to teach students the techniques of solving specific (practical) or more complex problems. Following an introduction to fundamental notions and concepts of modern nonlinear dynamics, the text goes on to set out the basics of stability theory, as well as bifurcation theory in one and two-dimensional cases. Foundations of asymptotic methods and the theory of relaxation oscillations are presented, with much attention paid to a method of mappings and its applications. With each chapter including exercises and solutions, including computer problems, this book can be used in courses on oscillation theory for physics and engineering students. It also serves as a good reference for students and scientists in computational neuroscience.

"Nonlinear Oscillations in Mechanical Engineering" explores the effects of nonlinearities encountered in applications in that field. Since the nonlinearities are caused, first of all, by contacts between different mechanical parts, the main part of this book is devoted to oscillations in mechanical systems with discontinuities caused by dry friction and collisions. Another important source of nonlinearity which is covered is that caused by rotating unbalanced parts common in various machines as well as variable inertias occurring in all kinds of crank mechanisms. This book is written for advanced undergraduate and postgraduate students, but it may be also helpful and interesting for both theoreticians and practitioners working in the area of mechanical engineering at universities, in research labs or institutes and especially in the R and D departments within industrial firms.

This book provides working tools for the study and design of nonlinear dynamical systems applicable in physics and engineering. It offers a broad-based introduction to this challenging area of study, taking an applications-oriented approach that emphasizes qualitative analysis and approximations rather than formal mathematics or simulation. The author, an internationally recognized authority in the field, makes extensive use of examples and includes executable Mathematica notebooks that may be used to generate new examples as hands-on exercises. The coverage includes discussion of mechanical models, chemical and ecological interactions, nonlinear oscillations and chaos, forcing and synchronization, spatial patterns and waves. Key Features: · Written for a broad audience, avoiding dependence on mathematical formulations in favor of qualitative, constructive treatment. · Extensive use of physical and engineering applications. · Incorporates Mathematica notebooks for simulations and hands-on self-study. · Provides a gentle but rigorous introduction to real-world nonlinear problems. · Features a final chapter dedicated to applications of dynamical systems to spatial patterns. The book is aimed at student and researchers in applied mathematics and mathematical modelling of physical and engineering problems. It teaches to see common features in systems of different origins, and to apply common methods of study without losing sight of complications and uncertainties related to their physical origin.

Bridging the gap between elementary courses and the research literature in this field, the book covers the basic concepts necessary to study differential equations. Stability theory is developed, starting with linearisation methods going back to Lyapunov and Poincaré, before moving on to the global direct method. The Poincaré-Lindstedt method is introduced to approximate periodic solutions, while at the same time proving existence by the implicit

function theorem. The final part covers relaxation oscillations, bifurcation theory, centre manifolds, chaos in mappings and differential equations, and Hamiltonian systems. The subject material is presented from both the qualitative and the quantitative point of view, with many examples to illustrate the theory, enabling the reader to begin research after studying this book.

This book covers both classical and modern analytical methods in nonlinear systems. A wide range of applications from fundamental research to engineering problems are addressed. The book contains seven chapters, each with miscellaneous problems and their detailed solutions. More than 100 practice problems are illustrated, which might be useful for students and researchers in the areas of nonlinear oscillations and applied mathematics. With providing real world examples, this book shows the multidisciplinary emergence of nonlinear dynamical systems in a wide range of applications including mechanical and electrical oscillators, micro/nano resonators and sensors, and also modelling of global warming, epidemic diseases, sociology, chemical reactions, biology and ecology.

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This text maps out the modern theory of non-linear oscillations. The material is presented in a non-traditional manner and emphasises the new results of the theory - obtained partially by the author, who is one of the leading experts in the area. Among the topics are: synchronization and chaotization of self-oscillatory systems and the influence of weak random vibration on modification of characteristics and behaviour of the non-linear systems.

This book is an ideal text for advanced undergraduate students and graduate students with an interest in the qualitative theory of ordinary differential equations and dynamical systems. Elementary knowledge is emphasized by the detailed discussions on the fundamental theorems of the Cauchy problem, fixed-point theorems (especially the twist theorems), the principal idea of dynamical systems, the nonlinear oscillation of Duffing's equation, and some special analyses of particular differential equations. It also contains the latest research by the author as an integral part of the book.

In this book, bifurcational mechanisms of the development, structure and properties of chaotic attractors are investigated by numerical and physical experiments based on the methods of the modern theory of nonlinear oscillations. The typical bifurcations of regular and chaotic attractors which are due to parameter variations are analyzed. Regularities of the transition to chaos via the collapse of quasiperiodic oscillations with two and three frequencies are investigated in detail. The book deals with the problems of chaotic synchronization, interaction of attractors and the phenomenon of stochastic resonance. The problems of fluctuation influence on the bifurcations and properties of chaotic attractors are investigated more closely. All principal problems are investigated by the comparison of theoretical and numerical results and data from physical experiments.

This book emphasizes those topological methods (of dynamical systems) and theories that are useful in the study of different classes of nonautonomous evolutionary equations. The content is developed over six chapters, providing a thorough introduction to the techniques used in the Chapters III-VI described by Chapter I-II. The author gives a systematic treatment of the basic mathematical theory and constructive methods for Nonautonomous Dynamics. They show how these diverse topics are

connected to other important parts of mathematics, including Topology, Functional Analysis and Qualitative Theory of Differential/Difference Equations. Throughout the book a nice balance is maintained between rigorous mathematics and applications (ordinary differential/difference equations, functional differential equations and partial difference equations). The primary readership includes graduate and PhD students and researchers in the field of dynamical systems and their applications (control theory, economic dynamics, mathematical theory of climate, population dynamics, oscillation theory etc).

This introduction to applied nonlinear dynamics and chaos places emphasis on teaching the techniques and ideas that will enable students to take specific dynamical systems and obtain some quantitative information about their behavior. The new edition has been updated and extended throughout, and contains a detailed glossary of terms. From the reviews: "Will serve as one of the most eminent introductions to the geometric theory of dynamical systems."

--Monatshefte für Mathematik

A rich variety of books devoted to dynamical chaos, solitons, self-organization has appeared in recent years. These problems were all considered independently of one another. Therefore many of readers of these books do not suspect that the problems discussed are divisions of a great generalizing science - the theory of oscillations and waves. This science is not some branch of physics or mechanics, it is a science in its own right. It is in some sense a meta-science. In this respect the theory of oscillations and waves is closest to mathematics. In this book we call the reader's attention to the present-day theory of non-linear oscillations and waves. Oscillatory and wave processes in the systems of diversified physical natures, both periodic and chaotic, are considered from a unified point of view. The relation between the theory of oscillations and waves, non-linear dynamics and synergetics is discussed. One of the purposes of this book is to convince reader of the necessity of a thorough study popular branches of the theory of oscillations and waves, and to show that such science as non-linear dynamics, synergetics, soliton theory, and so on, are, in fact, constituent parts of this theory. The primary audiences for this book are researchers having to do with oscillatory and wave processes, and both students and post-graduate students interested in a deep study of the general laws and applications of the theory of oscillations and waves.

The book is a collection of contributions devoted to analytical, numerical and experimental techniques of dynamical systems, presented at the International Conference on Dynamical Systems: Theory and Applications, held in Łódź, Poland on December 2-5, 2013. The studies give deep insight into both the theory and applications of non-linear dynamical systems, emphasizing directions for future research. Topics covered include: constrained motion of mechanical systems and tracking control; diversities in the inverse dynamics; singularly perturbed ODEs with periodic coefficients; asymptotic solutions to the problem of vortex structure around a cylinder; investigation of the regular and chaotic dynamics; rare phenomena and chaos in power converters; non-holonomic constraints in wheeled robots; exotic bifurcations in non-smooth systems; micro-chaos; energy exchange of coupled oscillators; HIV dynamics; homogenous transformations with applications to off-shore slender structures; novel approaches to a qualitative study of a dissipative system; chaos of postural sway in humans; oscillators with fractional derivatives; controlling chaos via bifurcation diagrams; theories relating to optical choppers with rotating wheels; dynamics in expert systems; shooting methods for non-standard boundary value problems; automatic sleep scoring governed by delay differential equations; isochronous oscillations; the aerodynamics pendulum and its limit cycles; constrained N-body problems; nano-fractal oscillators and dynamically-coupled dry friction.

A unified and coherent treatment of analytical, computational and experimental techniques of

nonlinear dynamics with numerous illustrative applications. Features a discourse on geometric concepts such as Poincaré maps. Discusses chaos, stability and bifurcation analysis for systems of differential and algebraic equations. Includes scores of examples to facilitate understanding.

Bifurcation and Chaos has dominated research in nonlinear dynamics for over two decades and numerous introductory and advanced books have been published on this subject. There remains, however, a dire need for a textbook which provides a pedagogically appealing yet rigorous mathematical bridge between these two disparate levels of exposition. This book is written to serve the above unfulfilled need. Following the footsteps of Poincaré, and the renowned Andronov school of nonlinear oscillations, this book focuses on the qualitative study of high-dimensional nonlinear dynamical systems. Many of the qualitative methods and tools presented in this book were developed only recently and have not yet appeared in a textbook form. In keeping with the self-contained nature of this book, all topics are developed with an introductory background and complete mathematical rigor. Generously illustrated and written with a high level of exposition, this book will appeal to both beginners and advanced students of nonlinear dynamics interested in learning a rigorous mathematical foundation of this fascinating subject. Contents: Basic Concepts Structurally Stable Equilibrium States of Dynamical Systems Structurally Stable Periodic Trajectories of Dynamical Systems Invariant Tori Center Manifold. Local Case Center Manifold. Non-Local Case Readership: Engineers, students, mathematicians and researchers in nonlinear dynamics and dynamical systems. Keywords: Bifurcations; Dynamical Systems; Qualitative Theory; Chaos; Strange Attractors; Nonlinear Dynamics Reviews: "It is well-written and clearly organized with excellent figures ... This rigorous book, with its emphasis on mathematical technique, would form an excellent basis for an engineering course if supplemented with applications." Applied Mechanics Reviews "Short remarks concerning various, not only mathematical, aspects of the theory add an extra flavour to the text. I recommend the book for all persons interested in the qualitative theory of differential equations." Mathematical Reviews

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