

Preface

The purpose of this text, **It's a Nonlinear World**, is to prepare science and engineering students for the “real” world where problems and issues on the frontiers of modern scientific, technological, economic, and social research are often nonlinear in nature. In this nonlinear world, many of the mathematical concepts and tools learned and applied in traditional undergraduate, and even graduate, science courses are simply inadequate and new mathematical tools must be introduced. This text will supply these tools and then illustrate how they are used, drawing examples from diverse fields in the physical, chemical, biological, engineering, medical, and social sciences.

The book is divided into two parts, the first section introducing the reader to nonlinear dynamical (evolving with time) systems in the **World of Mathematics**. In the opening chapter of this section, we examine what is meant by a nonlinear mathematical system, providing a variety of historically important, as well as current, examples formulated in terms of ordinary differential equations (ODEs) and finite difference equations (“maps”). Since exact analytic solutions to nonlinear ODE model equations of importance in the real world generally do not exist, the reader is introduced to some of the more common numerical algorithms for solving these equations on the computer.

In the subsequent three chapters of the **World of Mathematics**, we systematically present the mathematical framework of nonlinear dynamics. The material is organized according to mathematical structure, namely, nonlinear ODEs, nonlinear maps, and similarity and soliton solutions of nonlinear PDE (partial differential equation) models. In these chapters, the reader is introduced to such nonlinear concepts as fixed points, bifurcations, limit cycles, fractals, chaos, solitons, etc., and nonlinear diagnostic tools such as fixed point analysis, bifurcation diagrams, Lyapunov exponents, and so on.

The second part (**Our Nonlinear World**) of the book presents illustrative examples of nonlinear dynamics in the real world grouped in the following seven chapters:

- **World of Motion**
- **World of Sports**
- **World of Electromagnetism**
- **World of Weather Prediction**
- **World of Chemistry**
- **World of Disease**
- **World of War**

Each chapter provides topics which are highly relevant to the contemporary world and makes extensive use of the ideas and methods introduced in the first part of the text. Such a selection of topics and examples is inherently bound to be uneven, reflecting not only the background and knowledge of the author but also the fact that the nonlinear universe is vast and we are able to sample only a small portion of it. The examples range from the flight of a major baseball league curve ball, to the origin of the earth's magnetic field, to the spread of an epidemic, to the conflict between different ant colonies, and to the inherent difficulty in long-range weather forecasting, to mention just a few of the intellectual treats that will be presented. All the examples are fully referenced to the published literature or the Internet so that they can be more fully explored if desired. The Internet is becoming a rich source of information with many nonlinear scientists making copies of their published (and refereed) papers available online. Journals, on the other hand, do not provide online copies of published papers free of charge, so a visit to a university or college library may be necessary to view these papers.

The mathematical level of the text assumes a good working knowledge of basic calculus (ordinary and partial derivatives, integrals, etc.) and a reasonable familiarity with differential equations. To keep the text as mathematically simple as possible, the overwhelming number of examples are formulated in terms of nonlinear ODEs and maps. With the exception of seeking soliton and similarity solutions in certain cases by reducing PDEs to ODEs, the coverage of most PDE models in this text tends to generally be more qualitative than quantitative.

It's a Nonlinear World may be used as a course text or for self-study, but is written in such a way that the more casual mathematically literate reader can simply read the book for intellectual enjoyment and enlightenment. A wide variety of exercises and problems are provided at the end of each chapter which allow the reader to explore other nonlinear models and, if desired, to test his or her mastery of the subject matter.

This book is intended to be open-ended, aimed at whetting the appetite of the reader to more fully explore our nonlinear world. Entire regions of this world, such as nonlinear modeling in economics, have not been traversed in this text and remain for you to discover what treats lie therein.

It's a Nonlinear World

Enns, R.H.

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