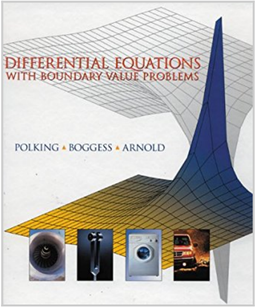

Differential Equations with Boundary Value Problems

By John Polking, Albert Boggess, David Arnold

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This book strikes a balance between the traditional and the modern—combining the traditional material with a modern systems emphasis. Chapter topics cover an introduction to differential equations, first-order equations, modeling and applications, second-order equations, the Laplace Transform, numerical methods, matrix algebra, an introduction to systems, linear systems with constant coefficients, nonlinear systems, power series solutions, Fourier series methods, and partial differential equations.

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Editorial Review

From the Back Cover
This book strikes a balance between the traditional and the modern—combining the traditional material with a modern systems emphasis. Chapter topics cover an introduction to differential equations, first-order equations, modeling and applications, second-order equations, the Laplace Transform, numerical methods, matrix algebra, an introduction to systems, linear systems with constant coefficients, nonlinear systems, power series solutions, Fourier series methods, and partial differential equations.

This book started in 1993, when the first author began to reorganize the teaching of ODEs at Rice University. It soon became apparent that a textbook was needed that brought to the students the expanded outlook that modern developments in the subject required, and the use of technology allowed. Over the ensuing years this book has evolved.

The mathematical subject matter of this book has not changed dramatically from that of many books published ten or even twenty years ago. The book strikes a balance between the traditional and the modern. It covers all of the traditional material and somewhat more. It does so in a way that makes it easily possible, but not necessary, to use modern technology, especially for the visualization of the ideas involved in ordinary differential equations. It offers flexibility of use that will allow instructors at a variety of institutions to use the book. In fact, this book could easily be used in a traditional differential equations course, provided the instructor carefully chooses the exercises assigned. However, there are changes in our students, in our world, and in our mathematics that require some changes in the ODE course, and the way we teach it.

Our students are now as likely to be majoring in the biological sciences or economics as in the physical sciences or engineering. These students are more interested in systems of equations than they are in second-order equations. They are also more interested in applications to their own areas rather than to physics or engineering.

Our world is increasingly a technological world. In academia we are struggling with the problem of adapting to this new world. The easiest way to start a spirited discussion in a group of faculty is to raise the subject of the use of technology in our teaching. Regardless of one's position on this subject, it is widely agreed that the course where the use of technology makes the most sense, and where the impact of computer visualization is the most beneficial, is in the study of ODEs. The use of computer visualization pervades this book. The degree to which the student and the instructor are involved is up to the instructor.

The subject of ordinary differential equations has progressed, as has all of mathematics. To many it is now known by the new name, dynamical systems. Much of the progress, and many of the directions in which the research has gone, have been motivated by computer experiments. Much of the work is qualitative in nature. This is beautiful mathematics. Introducing some of these ideas to students at an early point is a move in the right direction. It gives them a better idea of what mathematics is about than the standard way of discussing one solution method after another. It should be emphasized that the introduction of qualitative methods is not, in itself, a move to less rigor.

The Use of Technology

The book covers the standard material with an appropriate level of rigor. However, it enables the instructor to be flexible in the use of modern technology. Available to all, without the use of any technology, is the large number of graphics in the book that display the ideas in ODEs. At the next level are a large number of exercises that require the student to compute and plot solutions. For these exercises, the student will have to have access to computer (or calculator) programs that will do this easily.

The tools needed for most of these exercises are two. The student will need a program that will plot the direction field for a single differential equation, and superimpose the solution with given initial conditions. In addition, the student will need a program that will plot the vector field for an autonomous planar system of equations, and superimpose the solution with given initial conditions. Such tools are available in MATLAB, Maple, and Mathematica. For many purposes it will be useful for the students to have computer (or calculator) tools for graphing functions of a single variable.

The book can also be used to teach a course in which the students learn numerical methods early and are required to use them regularly throughout the course. Students in such a course learn the valuable skill of solving equations and systems of equations numerically and interpreting the results using the subject matter of the course. The treatment of numerical methods is somewhat more substantial than in other books. However, just enough is covered so that readers get a sense of the complexity involved. Computational error is treated, but not so rigorously as to bog the reader down and interrupt the flow of the text. Students are encouraged to do some experimental analysis of computational error.

Modeling and Applications

It is becoming a common feature of mathematics books to include a large list of applications. Usually the students are presented with the mathematical model and they are required to apply it to a variety of cases. The derivation of the model is not done. There is some sense in this. After all, mathematics does not include all of the many application areas, and the derivation of the models is the subject of the application areas. Furthermore, the derivations are very time consuming.

However, mathematicians and mathematics are part of the modeling process. It should be a greater part of our teaching. This book takes a novel approach to the teaching of modeling. While a large number of applications are covered as examples, in some cases the applications are covered in more detail than is usual. There is a historical study of the models of motion, which demonstrates to students how models continue to evolve as knowledge increases. There is an in-depth study of several population models, including their derivation. Included are historical examples of how such models were applied both where they were appropriate and where they were not. This demonstrates to students that it is necessary to understand the assumptions that lie behind a model before using them, and that any model must be checked by experiments or observations before it is accepted.

In addition, models in personal finance are discussed. This is an area of potential interest to all students, but not one that is covered in any detail in college courses. Students majoring in almost all disciplines approach these problems on an even footing. As a result it is an area where students can be required to do some modeling on their own.

Linear Algebra and Systems

Most books at this level assume that students have an understanding of elementary matrix algebra, usually in two and three dimensions. In the experience of the authors this assumption is not valid. Accordingly, this book devotes a chapter to matrix algebra. The topics covered are carefully chosen to be those needed in the study of linear systems of ODEs. With this chapter behind them, the instructor can cover linear systems of ODEs in a more substantive way. On the other hand an instructor who is confident in the knowledge of the students can skip the matrix algebra chapter.

Projects

There are a number of projects discussed in the book. These involve students in an in-depth study of either mathematics or an application that uses ODEs. The projects provide students with the opportunity to bring together much of what they have learned, including analytical, computational, and interpretative skills. The level of difficulty of the projects varies. More projects will be made available to users of this book as they are developed.

Varied Approaches Possible

It should be noticed that the book has three authors from three very different schools. The ODE courses at these institutions are quite different. Indeed, there is no standard ODE course across the country. The authors set the understandable goal of writing a book that could be used in the ODE courses at each of their own institutions. Meeting this goal required some compromises, but the result is a book that is flexible enough to allow its use in a variety of courses at a variety of institutions.

On one hand, it is possible to use the book and teach a more or less standard course. The standard material is covered in the standard order, with or without the use of technology.

However, at Rice University, after the first three chapters the class moves to numerical methods, and then to matrix algebra. This is followed by linear systems. Once this material is covered, higher-order equations, including the second-order equations that are important in science and engineering, are covered as examples of systems. This approach allows the students to use linear algebra throughout the course, thereby gaining a working knowledge of the subject. Technology is used throughout to enhance the students' understanding of the mathematical ideas.

In another approach, used at College of the Redwoods, the chapter on numerical methods is done early, while discussing the qualitative analysis of single first-order equations. The students are taught the analytical, qualitative, and numerical approaches before moving on to Chapter 3. The chapter on matrix algebra is covered next. There follows an introduction of systems, both linear and nonlinear. Next, they return to second-order equations, including undetermined coefficients, the driven, damped oscillator, resonance, and so forth. The course ends with more on nonlinear systems. The ultimate goal is to get the students to use nullcline analysis and the Jacobian approximation to sketch a phase portrait without the use of software.

Mathematical Rigor

Mathematical ideas are not dodged. Proofs are given when the proof will add to the students' understanding of the material. Difficult proofs, or those that do not add to a student's understanding, are avoided. Suggestions of how to proceed, and examples that use these suggestions, are usually offered as motivation before one has to wade through the abstraction of a proof. The authors believe that proof is fundamental to mathematics, and that students at this level should be introduced gently to proof as an integral part of their training in mathematics. This is true for the future engineer or doctor as well as for the math major.

Additional Material

The last three chapters of this version contain the solution of boundary value problems and the material needed for that. Chapter 11 is a fairly standard treatment of series solutions. In Chapter 12 we treat Fourier series. This is an expanded version of what appears in most books, including complex Fourier series and the discrete Fourier transform. Since this material is becoming of greater interest, some instructors might want to include it in their courses. In the final chapter, we treat boundary value problems. The way this material is taught is changing, and we have tried to make the treatment a little more modern, while not abandoning the traditional approach. We have added material on the d'Alembert solution to the wave equation, and put some emphasis on the eigenvalue problem for the Laplacian, and its importance in understanding the wave and heat equations in more than one space dimension.

Supplements

Instructors who use this book will have available a number of resources. There are an Instructor's Solution Manual, containing the complete solutions to all of the exercises, and a Student's Solution Manual with the solutions to the odd-numbered exercises.

One way to meet the software needs of the student is to use the programs dfield and pplane, written by the first author for use with MATLAB. These programs are described in the book *Ordinary Differential Equations Using MATLAB* (ISBN 0-13-011381-6), written by two of the authors of this book. That book is available shrink-wrapped with this one at no extra cost (ISBN 0-13-079497-X). However, it should be emphasized that it is not necessary to use dfield and pplane with this book. There are many other possibilities.

The Web site **http://www.prenhall.com/polking** is a resource that will ultimately become very valuable to both instructors and students. Interactive java versions of the direction field program dfield and the phase plane program pplane will be accessible from this site. It will also provide animations of the examples in the book, links to other Web resources involving differential equations, and true-false quizzes on the subject matter. As additional projects are developed for use with the book, they will be accessible from the Web site.

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From reader reviews:

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