

PREFACE

This book is designed to support a one-semester course in numerical methods. It has been written for students who want to learn and apply numerical methods in order to solve problems in engineering and science. As such, the methods are motivated by problems rather than by mathematics. That said, sufficient theory is provided so that students come away with insight into the techniques and their shortcomings.

MATLAB[®] provides a great environment for such a course. Although other environments (e.g., Excel/VBA, Mathcad) or languages (e.g., Fortran 90, C++) could have been chosen, MATLAB presently offers a nice combination of handy programming features with powerful built-in numerical capabilities. On the one hand, its M-file programming environment allows students to implement moderately complicated algorithms in a structured and coherent fashion. On the other hand, its built-in, numerical capabilities empower students to solve more difficult problems without trying to “reinvent the wheel.”

The basic content, organization, and pedagogy of the second edition are essentially preserved in the third edition. In particular, the conversational writing style is intentionally maintained in order to make the book easier to read. This book tries to speak directly to the reader and is designed in part to be a tool for self-teaching.

That said, this edition differs from the past edition in three major ways: (1) two new chapters, (2) several new sections, and (3) revised homework problems.

1. **New Chapters.** As shown in Fig. P.1, I have developed two new chapters for this edition. Their inclusion was primarily motivated by my classroom experience. That is, they are included because they work well in the undergraduate numerical methods course I teach at Tufts. The students in that class typically represent all areas of engineering and range from sophomores to seniors with the majority at the junior level. In addition, we typically draw a few math and science majors. The two new chapters are:
 - **Eigenvalues.** When I first developed this book, I considered that eigenvalues might be deemed an “advanced” topic. I therefore presented the material on this topic at the end of the semester and covered it in the book as an appendix. This sequencing had the ancillary advantage that the subject could be partly motivated by the role of eigenvalues in the solution of linear systems of ODEs. In recent years, I have begun

PART ONE Modeling, Computers, and Error Analysis	PART TWO Roots and Optimization	PART THREE Linear Systems	PART FOUR Curve Fitting	PART FIVE Integration and Differentiation	PART SIX Ordinary Differential Equations
CHAPTER 1 Mathematical Modeling, Numerical Methods, and Problem Solving	CHAPTER 5 Roots: Bracketing Methods	CHAPTER 8 Linear Algebraic Equations and Matrices	CHAPTER 14 Linear Regression	CHAPTER 19 Numerical Integration Formulas	CHAPTER 22 Initial-Value Problems
CHAPTER 2 MATLAB Fundamentals	CHAPTER 6 Roots: Open Methods	CHAPTER 9 Gauss Elimination	CHAPTER 15 General Linear Least-Squares and Nonlinear Regression	CHAPTER 20 Numerical Integration of Functions	CHAPTER 23 Adaptive Methods and Stiff Systems
CHAPTER 3 Programming with MATLAB	CHAPTER 7 Optimization	CHAPTER 10 LU Factorization	CHAPTER 16 Fourier Analysis	CHAPTER 21 Numerical Differentiation	CHAPTER 24 Boundary-Value Problems
CHAPTER 4 Roundoff and Truncation Errors	CHAPTER 11 Matrix Inverse and Condition	CHAPTER 17 Polynomial Interpolation	CHAPTER 18 Splines and Piecewise Interpolation		
	CHAPTER 12 Iterative Methods	CHAPTER 13 Eigenvalues			

FIGURE P.1

An outline of this edition. The shaded areas represent new material. In addition, several of the original chapters have been supplemented with new topics.

to move this material up to what I consider to be its more natural mathematical position at the end of the section on linear algebraic equations. By stressing applications (in particular, the use of eigenvalues to study vibrations), I have found that students respond very positively to the subject in this position. In addition, it allows me to return to the topic in subsequent chapters which serves to enhance the students' appreciation of the topic.

- **Fourier Analysis.** In past years, if time permitted, I also usually presented a lecture at the end of the semester on Fourier analysis. Over the past two years, I have begun presenting this material at its more natural position just after the topic of linear least squares. I motivate the subject matter by using the linear least-squares approach to fit sinusoids to data. Then, by stressing applications (again vibrations), I have found that the students readily absorb the topic and appreciate its value in engineering and science.

It should be noted that both chapters are written in a modular fashion and could be skipped without detriment to the course's pedagogical arc. Therefore, if you choose, you can either omit them from your course or perhaps move them to the end of the semester. In any event, I would not have included them in the current edition if they did not represent an enhancement within my current experience in the classroom. In particular, based on my teaching evaluations, I find that the stronger, more motivated students actually see these topics as highlights. This is particularly true because MATLAB greatly facilitates their application and interpretation.

2. **New Content.** Beyond the new chapters, I have included new and enhanced sections on a number of topics. The primary additions include sections on animation (Chap. 3), Brent's method for root location (Chap. 6), *LU* factorization with pivoting (Chap. 8), *random numbers* and *Monte Carlo simulation* (Chap. 14), *adaptive quadrature* (Chap. 20), and *event* termination of ODEs (Chap. 23).
3. **New Homework Problems.** Most of the end-of-chapter problems have been modified, and a variety of new problems have been added. In particular, an effort has been made to include several new problems for each chapter that are more challenging and difficult than the problems in the previous edition.

Aside from the new material and problems, the third edition is very similar to the second. In particular, I have endeavored to maintain most of the features contributing to its pedagogical effectiveness including extensive use of worked examples and engineering and scientific applications. As with the previous edition, I have made a concerted effort to make this book as "student-friendly" as possible. Thus, I've tried to keep my explanations straightforward and practical.

Although my primary intent is to empower students by providing them with a sound introduction to numerical problem solving, I have the ancillary objective of making this introduction exciting and pleasurable. I believe that motivated students who enjoy engineering and science, problem solving, mathematics—and yes—programming, will ultimately make better professionals. If my book fosters enthusiasm and appreciation for these subjects, I will consider the effort a success.

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It should be stressed that although I received useful advice from the aforementioned individuals, I am responsible for any inaccuracies or mistakes you may find in this book. Please contact me via e-mail if you should detect any errors.

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