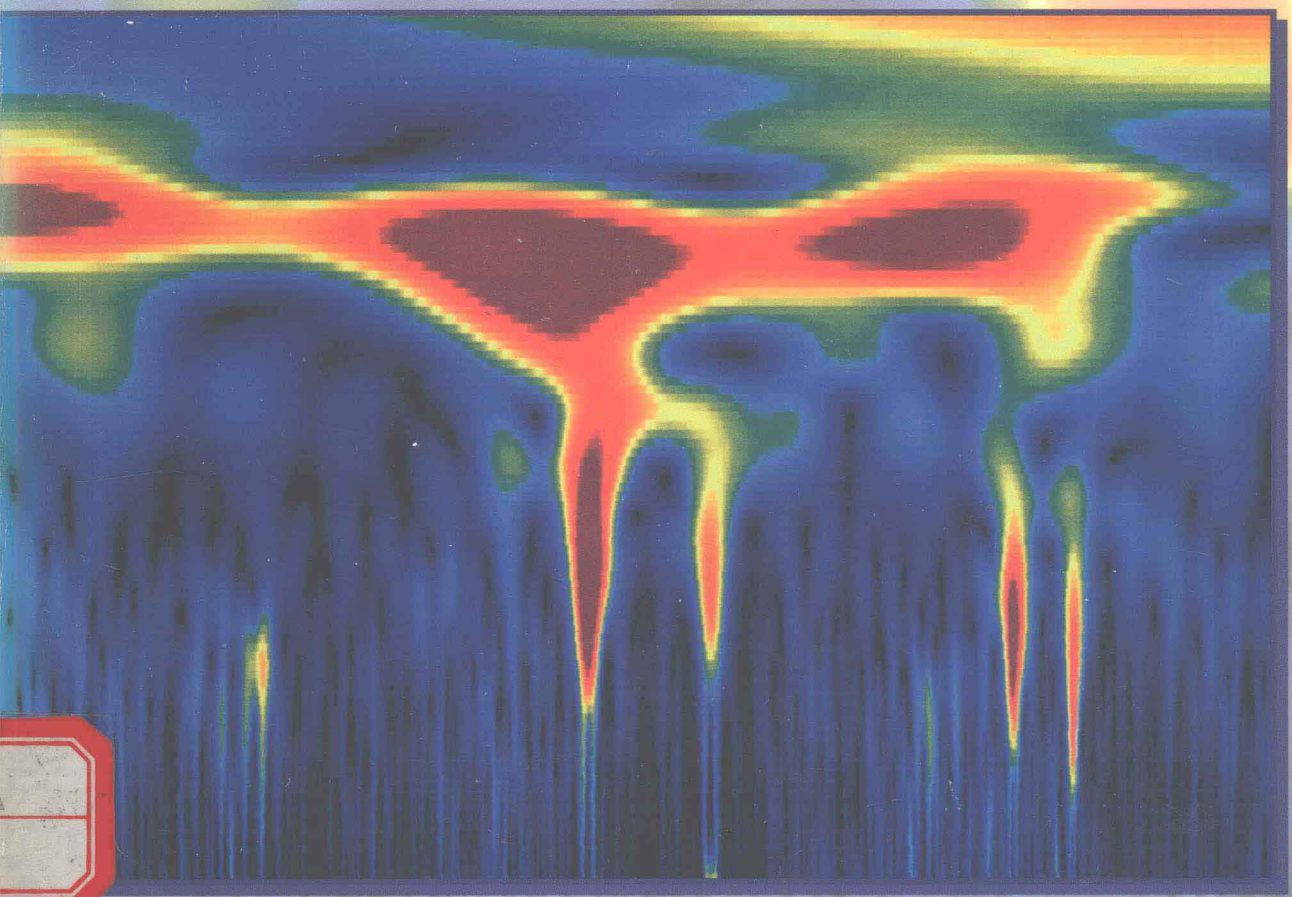
ENGINEERING PROBLEM SOLVING WITH MATLAB®

Second Edition



Delores M. Etter

MATLAB® Curriculum Series

Engineering Problem Solving with MATLAB®

Second Edition

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An Alan R. Apt Book

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In memory of my dearest Mother, Muerladene Janice Van Camp

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Foreword

This is an exciting and unusual textbook. It is exciting because it represents a new approach to an important aspect of engineering education. It is unusual because it combines topics from what are traditionally three or four different courses into a single, introductory course. This new course, intended for freshman or sophomore students in engineering and science, covers

- Elementary applied mathematics
- Basic numerical methods
- Computer programming
- Problem solving methodology

Where do you first see complex numbers? Where do you first learn about 3-by-3 matrices? When do you begin to do useful mathematical computations? How do you combine these ideas into the solution of practical engineering and scientific problems? This book provides answers to such questions early in the collegiate career.

One exercise in the book illustrates this multi-faceted approach:

Write a MATLAB expression for the resistance of three resistors in parallel.

Here, in one problem, we have some basic electrical engineering, some elementary mathematics, and a little bit of computer programming.

Thirteen years ago, Delores Etter wrote two popular textbooks on computer programming and numerical methods. She chose to use Fortran which then was clearly the most widely used language for technical computing. Coincidentally, about this same time MATLAB began to be used outside of the matrix computation community where it originated.

Today, there is a wide variety of languages and environments available for technical computing. Fortran is certainly still important; but so are Pascal, C, and C++. There are sophisticated programmable calculators, spread sheets, and mouse- and menu-based systems. And there are several commercial mathematical languages. In our opinion, MATLAB is the right choice for courses such as this because it is

- Easy to learn and use
- Powerful, flexible, and extensible
- Accurate, robust, and fast
- Widely used in engineering and science
- Backed by a professional software company

At The MathWorks and at Prentice Hall, we are committed to the support of MATLAB's use in education. In the future, you will see new features added to The Student Edition and many new books available in the MATLAB Curriculum Series.

A friend of ours, who is a professor of electrical engineering and an expert on signal processing, says "MATLAB is so good for signal processing because it wasn't designed to do signal processing—it was designed to do mathematics."

Our friend's observation is also the basis for this book. Mathematics, and its embodiment in software, is a foundation for much of modern technology. We believe you will enjoy, and benefit from, this introduction.

Cleve Moler
The MathWorks, Inc.
Natick, Massachusetts

Preface

Engineers and scientists use computers to solve a variety of problems, ranging from the evaluation of a simple function to solving a sytem of equations. MATLAB has become the **technical computing environment** of choice for many engineers and scientists because it is a single interactive system that incorporates **numeric computation, symbolic computation**, and **scientific visualization**.

Because the MATLAB computing environment is one that a new engineer is likely to encounter in a job, it is a good choice for an introduction to computing for engineers. This book is appropriate for use as an introductory engineering text or as a supplemental text in an advanced course. It is also useful as a professional reference.

This text was written to introduce engineering problem solving with the following objectives:

- Present a consistent **methodology for solving engineering problems**.
- Describe the exceptional **computational and visualization capabilities of MATLAB**.
- Illustrate the problem-solving process through a variety of **engineering examples and applications**.

To accomplish these objectives, Chapter 1 presents a five-step process that is used consistently for solving engineering problems. The rest of the chapters present the capabilities of MATLAB for solving engineering problems using specific examples from many different engineering disciplines. The text is based on **Version 4** of MATLAB; some of the new features in **Version 5** are discussed in supplemental materials that are available on the Prentice Hall World Wide Web site which is discussed later in this Preface.

TEXT ORGANIZATION

This flexible book is designed for use in a variety of engineering and science course settings from a primary text for introductory students to a supplement for intermediate or advanced courses. The text is divided into three parts—Part I: Fundamental Engineering Computing, Part II: Numerical Techniques, and Part III: Special Topics. Part I presents MATLAB material that is fundamental to basic engineering computing and visualization. The four chapters in Part I focus on the **MATLAB environment** and **MATLAB functions**. Part II contains four chapters that cover common numerical techniques for determining solutions to **systems of linear equations**, for **interpolation** and **curve fitting**, for **numerical integration** and **differentiation**, and for **solving ordinary differential equations**. These chapters

are independent of each other, but they do assume that the material in Part I has been covered. Finally, Part III contains three special topics that are very useful in solving more specialized engineering problems: **symbolic mathematics**, **signal processing**, and **control systems**.

It is feasible to cover Chapters 1 through 9 in a one-semester course for a complete presentation of MATLAB's capabilities. If a briefer introduction to MATLAB is desired, we suggest that Chapters 1 through 3 be covered along with selected topics from Chapters 5 through 8. We have also written another text, *Introduction to MATLAB for Engineers and Scientists* (Prentice Hall, 1996, 0-13-519703-1), that is especially designed for a brief (three- to six-week) introduction to the capabilities of MATLAB. The chapters on signal processing and control systems (included in Part III) are specialized chapters that require additional background. These chapters are included to provide reference material for advanced courses.

PREREQUISITES

No prior experience with the computer is assumed. The mathematical background needed for Chapters 1 through 6 is **college algebra** and **trigonometry**; more advanced mathematics is needed for some of the material in later chapters.

PROBLEM-SOLVING METHODOLOGY

The **emphasis on engineering and scientific problem solving** is an important part of this text. Chapter 1 introduces a **five-step process for solving engineering problems** using the computer:

1. State the problem clearly.
2. Describe the input and output information.
3. Work a simple example by hand.
4. Develop an algorithm and convert it to MATLAB.
5. Test the solution with a variety of data.

To reinforce the development of problem solving skills, each of these steps is identified every time a complete solution to an engineering problem is developed.

ENGINEERING AND SCIENTIFIC APPLICATIONS

Throughout the text, emphasis is placed on incorporating real-world engineering and scientific examples and problems with solutions and usable code. This emphasis is centered around a theme of **grand challenges**, which include

- prediction of weather, climate, and global change
- computerized speech understanding

- mapping of the human genome
- improvements in vehicle performance
- enhanced oil and gas recovery

Each chapter begins with a photograph and a discussion of some aspect of one of these grand challenges that provides a glimpse of some of the exciting and interesting areas in which engineers might work. The grand challenges are also referenced in many of the other examples and problems.

VISUALIZATION

The visualization of the information related to a problem is a key advantage of using MATLAB for developing and understanding solutions. Therefore, it is important to learn to generate **plots** in a variety of formats to use when analyzing, interpreting, and evaluating data. We begin using plots with the first MATLAB program presented in Chapter 1, and continually expand **plotting capabilities** within the remaining chapters.

SOFTWARE ENGINEERING CONCEPTS

Engineers and scientists are also expected to develop and implement **user-friendly** and **reusable** computer solutions. Therefore, learning software engineering techniques is crucial to successfully developing these computer solutions. **Readability** and **documentation** are stressed in the development of programs. Through MATLAB, users are able to write **portable** code that can be transferred from one computer platform to another. Additional topics that relate to software engineering issues are discussed throughout the text and include the **software life cycle**, **maintenance**, **modularity**, **abstraction**, and **software prototypes**.

THE INTERNET AND THE WORLD WIDE WEB

One of the new sections in this edition discusses the **Internet, electronic mail, electronic bulletin boards**, and the **World Wide Web**. Several web sites are listed that contain more information related to this text and to MATLAB.

EXERCISES AND PROBLEMS

Learning any new skill requires practice at a number of different levels of difficulty. **Practice! problems** are short-answer questions that relate to the section of material just presented. Most sections are immediately followed by a set of Practice! problems so readers can determine if they are ready to continue to the next section. Complete solutions to all the Practice! problems are included at the end of the text.

Each chapter ends with a set of **end-of-chapter problems**. These are new problems that relate to a variety of engineering applications with the level of dif-

ficulty ranging from straightforward to longer assignments. Engineering data sets are included for many of the problems to use in testing.

STUDENT AIDS

Margin notes are used to help the reader not only identify the important concepts, but also to locate specific topics easily. **Style notes** show how to write MATLAB statements that incorporate good software discipline while **debugging notes** help readers recognize common errors so that they can be avoided. The programming style notes are indicated with the margin note *Style*, and the debugging notes are indicated with a **bug icon**.

Each Chapter Summary reviews the topics covered in the chapter and includes a list of the **Key Terms** from the chapter; a summary of the style notes; and debugging notes; and a **MATLAB Summary** that lists all the special symbols, commands, and functions defined in the chapter. In addition, Appendix A contains a complete summary of MATLAB functions presented in the text, and the last two pages of the text contain commonly-used information.

INSTRUCTOR'S RESOURCES

An **Instructor's Manual** is available that contains complete solutions to all the end-of-chapter problems. Also, transparency masters are included to assist in preparing lecture material.

Additional information related to this text and to MATLAB is available through the World Wide Web. **Script files** and **data files** for examples used in this text, along with additional data files for end-of-chapter problems, are available at **`http://www.prenhall.com`**. The MathWorks, Inc., maintains a web site for **MATLAB information** at **`http://www.mathworks.com`**.

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I also want to express my gratitude to my husband, a mechanical/aerospace engineer, for his help in developing some of the engineering applications problems, and to my daughter, a veterinarian student, for her help in developing some of the DNA-related material and problems. Finally, I want to recognize the important contributions of the students in my introductory engineering courses for their feedback on the explanations, the examples, and the problems.

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