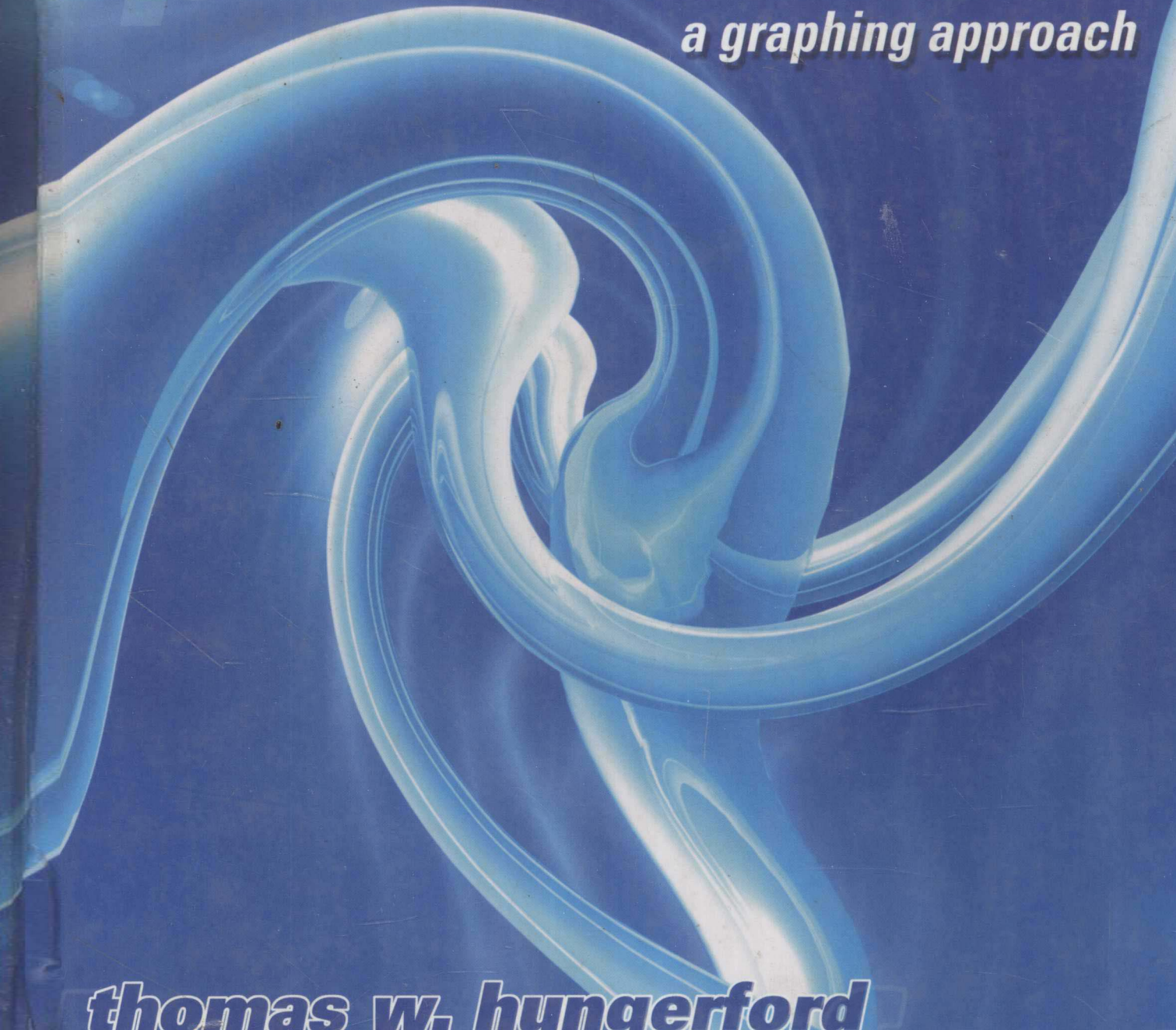
contemporary precalculus

a graphing approach



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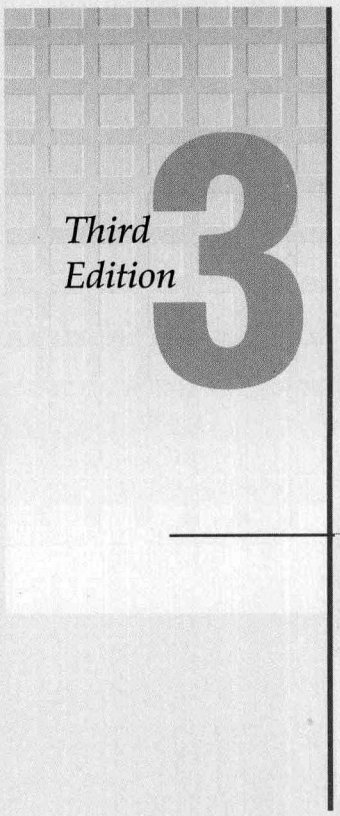

Contemporary Precalculus

A Graphing Approach

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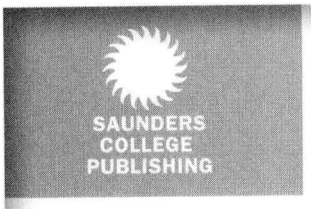

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Dedicated to the Parks sisters,

whose presence in my life has greatly enriched it:

To my aunt,

Irene Parks Mills

And to the memory of my mother,

Grace Parks Hungerford

and my aunt,

Florence M. Parks

Preface

This book is intended to provide the mathematical background needed in calculus by students with two or three years of high school mathematics. It integrates graphing technology into the course without losing sight of the fact that the underlying mathematics is the crucial issue. Mathematics is presented in an informal manner that stresses meaningful motivation, careful explanations, and numerous examples, with an ongoing focus on real-world problem solving.

The concepts that play a central role in calculus are explored from algebraic, graphical, and numerical perspectives. Students are expected to participate actively in the development of these concepts by using graphing calculators (or computers with suitable software), as directed in the *Graphing Explorations,* either to complete a particular discussion or to explore appropriate examples.

Changes in the Third Edition

A number of changes have been made in response to user requests.

Data Analysis and Mathematical Models Optional sections have been added, covering linear, polynomial, exponential and logarithmic models that can be constructed from data by using the regression capabilities of a calculator (Section 2.5, Excursion 4.4.A, and Section 5.5).

Trigonometry Chapter 6 has been significantly reordered, so as to have a more coherent and consistent presentation. As before, trigonometric functions are introduced as functions of a real number, rather than functions of an angle. This viewpoint is used consistently throughout the chapter (with all triangle trigonometry now in Chapter 7). Instructors now have considerably more flexibility than they did in the old arrangement. In particular, those who want to introduce all six trig functions simultaneously or who want to cover triangle trigonometry early can do so.

Rearrangement of Chapters 1–4 Material that is review for most students (including lines) is now in Chapter 1, with graphing technology being introduced in Chapter 2. Functions (including rates of change) are treated in Chapter 3, while Chapter 4 covers polynomial and rational functions (including quadratic functions).

Updated Technology Both the Technology Tips and the presentation of the texts have been revised to reflect the fact that most students have a computer or calculator at least at the level of the TI-83, Sharp 9600, Casio 9850, or HP-38, and many have next-generation calculators, such as the TI-89. Although these newer machines do not affect the underlying mathematical concepts, the wider range of tools that they make available requires some changes in how certain topics are approached.

Several parts of the book have been rewritten to improve clarity, including Sections 3.7 (Inverse Functions) and 4.3 (Real Roots of Polynomials). Other improvements to make the book more convenient to use are as follows.

Real-Data Applications A variety of new examples and exercises based on real-world data are now included in the text.

Chapter Openers Each chapter now begins with a brief example of an application of the mathematics treated in that chapter, together with a reference to an appropriate exercise. The opener also lists the titles of the sections in the chapter and, when necessary, provides a diagram showing their interdependence.

Discovery Projects Each chapter now ends with an investigative problem (suitable for small-group work) that allows students to apply some of the mathematics from the chapter in solving a real-world problem.

Functional Use of Color The effective use of a multi-color format makes the book more attractive and readable for both instructor and students.

An Electronic Companion to Precalculus CD-ROM The concepts in the text will be strengthened through the use of a CD-ROM that will be packaged with it. This dynamic and interactive CD-ROM covers the key concepts through multiple representations.

Mathematical and Pedagogical Features

The mathematical approaches to important topics in the second edition have been retained.

Functional notation and its uses are thoroughly treated.

The natural exponential and logarithmic functions are emphasized because of their central role in calculus.

Trigonometric functions of real numbers—the ones most widely used in calculus—are introduced first, with traditional triangle trigonometry treated later.

Parametric graphing is introduced early and used thereafter to illustrate such concepts as inverse functions, the definition of trigonometric functions, and the graphs of conic sections.

Average rates of change—a crucial concept for calculus—are fully treated and the calculator is used to explore the intuitive connections between average and instantaneous rates of change.

In addition to the *Graphing Explorations* mentioned in the second paragraph of this preface, all the other pedagogical features of the second edition are included here.

Cautions Students are alerted to common errors and misconceptions (both mathematical and technological) by clearly marked Caution boxes (formerly called Warnings).

Exercises Exercise sets proceed from routine calculations and drill to exercises requiring some thought, including graph interpretation and word problems. Some sets include problems labeled *Thinkers,* most of which are not difficult, but simply in a different form from what students may have seen before; a few of the *Thinkers* are quite challenging. Answers for odd-numbered problems are given in the back of the book, and solutions for these problems are in the Students Solutions Manual.

Chapter Reviews Each Chapter concludes with a list of important concepts (referenced by section and page number), a summary of important facts and formulas, and a set of review questions.

Algebra Review Basic algebra is reviewed in an appendix, which can be omitted by well-prepared students or covered as an introductory chapter if necessary.

Geometry Review Frequently used facts from plane geometry are summarized, with examples, in an appendix.

Finally, several technology assistance features have been retained and updated.

Technology Tips Although the discussion of technology in the text proper is as generic as possible, the Technology Tips in the margin provide information and assistance with carrying out various procedures on specific calculators.

Calculator Investigations Exercise sets in the early sections of the book are often preceded by Calculator Investigations that encourage students to become familiar with the capabilities and limitations of calculators (since many of them often don't realize what a calculator can—or can't—do).

Program Appendix This appendix provides a small number of programs that are useful either for updating older calculators (such as a table maker program for the TI-85) or for carrying out certain procedures discussed in the text (such as synthetic division).

Acknowledgments

I am particularly grateful to

Ann Steen, Santa Fe Community College

who served as a reviewer of the previous edition and supplied more than one hundred new exercises for this edition, to

Edward Miller, Lewis–Clark State College

who designed the Discovery Projects at the end of each chapter, and to our accuracy reviewer

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My sincere thanks go to the following reviewers who provided many helpful suggestions for improving this edition of the text:

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Finally, I want to thank the people who have prepared the various supplements that are available to instructors and students who use this book:

Instructor's Resource Manual: Matt Foss, North Hennepin Community College
Student Resource Manual: Matt Foss, North Hennepin Community College
Test Bank: Bruce Hoelter, Raritan Valley Community College; Elizabeth Hoelter, Moravian Academy
Graphing Calculator Manual: Joan McCarter, Arizona State University
Projects for Precalculus: Janet Anderson & Todd Swanson, Hope College; Robert Keeley, Calvin College
Digital Video Applications CD-ROM: Lori Palmer & Carolyn Hamilton, Utah Valley State College

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Cara Castiglio, Art Director

Their fine work has made my job much easier.

The last word goes to the love of my life, my wife Mary Alice, who has provided understanding and support when it was most needed.

Thomas W. Hungerford
Cleveland, Ohio
September 1999

To the Instructor

The following information should assist you in planning a workable syllabus for your course.

Prerequisites The Algebra Appendix is a prerequisite for the entire book and may be covered as Chapter 0, if necessary. Chapter 1 is also review material that may be omitted by well-prepared classes.

Interdependence of Chapters and Sections The chart on the facing page shows the interdependence of chapters. A similar chart appears at the beginning of each chapter, showing the interdependence of sections within the chapter. Note, in particular, that Chapters 4–6 (polynomial, exponential/logarithmic, and trigonometric functions) may be covered in any order.

Excursions Sections labeled Excursion are usually related to the preceding section and are never prerequisites for other sections of the text. The "Excursion" label is designed solely to make syllabus planning easier and is not intended as a kind of value judgement on the topic in question.

Limits and Continuity An optional chapter on these topics (that may be covered after Chapter 6) is published separately and is available at nominal cost to schools that adopt this text. Please contact your local sales representative for details.

In this text "calculator" means "graphing calculator." You and your students should be aware of the following facts about calculators.

Minimal Technology Requirements It is assumed that each student has either a computer with appropriate software or a calculator at least at the level of a TI-82. Among current calculator models that meet or exceed this minimal requirement are TI-82 through TI-92, Sharp 9600, HP-38, HP-48, and Casio 9850 and 9970. Although students with less powerful calculators may be able to handle much of the material, they will be at a disadvantage at a number of points.

(*text continues on p. xxii*)

Interdependence of Chapters

*Section 2.1 (Graphs and Graphing Calculators) is a prerequisite for Section 11.4 (Systems of Nonlinear Equations).

†Standard equations for conics (Sections 10.2 and 10.3) may be covered without using trigonometry.

Technology Tips To avoid much clutter, only a limited number of calculators are specifically mentioned in the Technology Tips. However, unless noted otherwise,

Technology Tips for the TI-83 also apply to the TI-82;

Technology Tips for the TI-86 also apply to the TI-85;

Technology Tips for the TI-89 also apply to the TI-92.

Technology Tips for the Casio 9850 also apply to the Casio 9970.

There are no Tips specifically for HP-48 calculators since they use entirely different operating systems than other calculators, but HP-48s are included in the Graphing Calculator Supplement available to students.

Supplements

Instructors who adopt this text may receive, free of charge, the following items

Electronic Companion to Precalculus CD-ROM This dynamic and interactive CD-ROM, which is packaged with the text, covers key concepts using multiple representations.

Instructor's Resource Manual Written by Matt Foss of North Hennepin Community College, this manual contains detailed solutions to all the exercises and end-of-chapter Review Questions to assist the instructor in the classroom and in grading assignments. Solutions to the Discovery Projects at the end of each chapter are also included.

Math in Practice: An Applied Video Companion CD-ROM This innovative ancillary packaged with the Instructor's Resource Manual is designed to show students how and where precalculus concepts arise in real-life. Over 20 engaging interviews conducted by Lori Palmer of Utah Valley State College with professionals from such fields as aviation, food services, banking, and environmental science motivate the key concepts from the text. Each vignette is accompanied by two problems written by Carolyn Hamilton of Utah Valley State College to test students' understanding of the underlying mathematical ideas and skills. Answers are provided on disk; detailed solutions are in the Instructor's Resource Manual.

Test Bank Written by Bruce Hoelter of Raritan Valley Community College, this manual provides over 2000 multiple-choice and open-ended questions arranged in 5 forms per chapter, each form containing about 30 questions. Master answer sheets and a complete answer section are included. Additionally, the Test Bank also includes a set of 20 practice problems for each chapter of the text with complete solutions.

Computerized Test Bank The computerized test bank contains all the test bank questions and allows instructors to prepare quizzes and examinations quickly and easily. Instructors may also add questions or

modify existing ones. The Computerized Test Bank has gradebook capabilities for recording and tracking students' grades. Instructors have the opportunity to post and administer a test over a network or on the Web. Its user-friendly printing capability accommodates all printing platforms.

Graphing Calculator Manual Written by Joan McCarter of Arizona State University, this manual covers several of the latest calculator models in more detail than do the Technology Tips in the text.

Projects for Precalculus Written by Hope College's Janet Andersen and Todd Swanson and Robert Keeley of Calvin College, this supplement stems from a popular and successful NSF-sponsored program in reform precalculus. The authors have conducted numerous workshops and compiled the feedback of over 100 class testers to create excellent precalculus applications. This manual contains carefully prepared and tested activities that promote conceptual understanding and active learning.

Video Series Free to adopters, the videotape package consists of 12 VHS videotapes, one for each chapter in the book. Each tape is an hour long and further develops the concepts of the chapter. On-location footage is utilized to introduce an extended application at the beginning of each tape. This application is explained fully at the end of the tape.

Website The Website (www.harcourtcollege.com/math/hungerford) offers additional resources to both instructors and students in conjunction with the adoption of the text. An on-line glossary allows students to confirm their understanding of important terms and theorems in the text. Web-based projects created by Gene Fiorini of Shippensburg University help develop the concepts in the text through researching Websites that cover a variety of topics.

WebCT Course This Web-based teaching and learning tool is free to instructors and students in conjunction with the adoption of the text. It allows instructors—with or without technical expertise—to create highly effective Web-based learning, communication, and collaboration environments. A full array of educational tools including testing, student tracking, access control, and much more are available.

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To the Student

This text assumes the use of technology, so you should be aware of the following facts.

Terminology In this text "calculator" means "graphing calculator." All discussions of calculators, with obvious modifications, apply to graphing software for computers.

Minimal Technology Requirements In order to use this text effectively, you must have either a computer with appropriate software or a calculator at least at the level of a TI-82. Among current models that meet or exceed this minimal requirement are the TI-82 through TI-92, the Sharp 9600, HP-38, HP-48, and Casio 9850 and 9970. Although students with less powerful calculators may be able to handle much of the material, they will be at a disadvantage at a number of points.

The following features of the text will enable you to get the most out of your calculator.

Technology Tips Some of the Technology Tips in the margin tell you the proper menus or keys to be used on specific calculators to carry out procedures mentioned in the text. Other Tips offer general information or helpful advice for performing a particular task on a calculator.

As a general rule, the only calculators mentioned in the Technology Tips are the TI-83, TI-86, TI-89, Sharp 9600, HP-38, Casio 9850*. However, unless noted otherwise,

Technology Tips for the TI-83 also apply to the TI-82;
Technology Tips for the TI-86 also apply to the TI-85;
Technology Tips for the TI-89 also apply to the TI-92;
Technology Tips for the Casio 9850 also apply to the Casio 9970.

*Although there are no Tips in the text specifically for HP-48 calculators, which use an entirely different operating system than other calculators, HP-48s are included in the Graphing Calculator Supplement, which is described below.

Calculator Investigations You may not be aware of the full capabilities of your calculator (or some of its limitations). The Calculator Investigations (which appear just before the exercise sets in some of the earlier sections of the book) will help you to become familiar with your calculator and to maximize the mathematical power it provides. Even if your instructor does not assign these investigations, you may want to look through them to be sure you are getting the most you can from your calculator.

With all this talk about calculators, don't lose sight of this crucial fact:

Technology is only a *tool* for doing mathematics.

You can't build a house if you only use a hammer. A hammer is great for pounding nails, but useless for sawing boards. Similarly, a calculator is great for computations and graphing, but it is not the right tool for every mathematical task. To succeed in this course, you must develop and use your algebraic and geometric skills, your reasoning power and common sense, and you must be willing to work.

The key to success is to use all of the resources at your disposal: your instructor, your fellow students, your calculator (and its instruction manual), and this book. Here are some tips for making the most of these resources.

Ask Questions. Remember the words of Hillel:

The bashful do not learn.

There is no such thing as a "dumb question" (assuming, of course, that you have attended class, taken notes, and read the text). Your instructor will welcome questions that arise from a serious effort on your part.

Read the Book. Not just the homework exercises, but the rest of the text as well. There is no way your instructor can possibly cover the essential topics, clarify ambiguities, explain the fine points, and answer all your questions during class time. You simply will not develop the level of understanding you need to succeed in this course and in calculus unless you read the text fully and carefully.

Be an Interactive Reader. You can't read a math book the way you read a novel or history book. You need pencil, paper, and your calculator at hand to work out the statements you don't understand and to make notes of things to ask your fellow students and/or your instructor.

Do the Graphing Explorations. When you come to a box labeled "Graphing Exploration," use your calculator as directed to complete the discussion. Typically, this will involve graphing one or more equations and answering some questions about the graphs. Doing these explorations as they arise will improve your understanding and clarify issues that might otherwise cause difficulties.

Do Your Homework. Remember that

Mathematics is not a spectator sport.

You can't expect to learn mathematics without doing mathematics, any more than you could learn to swim without getting wet. Like swimming or dancing or reading or any other skill, mathematics takes practice. Homework assignments are where you get the practice that is essential for passing this course and succeeding in calculus.

Supplements

The following items are available at no cost to students.

Electronic Companion to Precalculus CD-ROM This dynamic and interactive CD-ROM, which is packaged with the text, covers key concepts from a variety of different perspectives.

Website The Website (www.harcourtcollege.com/math/hungerford) includes an on-line glossary to assist you to confirm your understanding of important concepts and theorems in the text. Projects created by Gene Fiorini of Shippensburg University help develop the concepts in the text by researching Websites that cover a variety of topics.

WebCT Course If your instructor has made arrangements, this feature will provide an array of educational tools to assist you in learning the material in the course.

Students using Contemporary Precalculus may purchase the following supplements.

Student Resource Manual This manual, also written by Matt Foss, is comprised of two distinct parts. The first part consists of detailed solutions to all the odd-numbered Exercises and end-of-chapter Review Questions. Specific instructions for solving graphing calculator problems are included, as are accurate representations of graphing calculator screens. The Student Resource Manual also contains the **Math in Practice: An Applied Video Companion CD-ROM** and accompanying problems. This innovative ancillary is designed to show students how and where precalculus concepts arise in real life. Over 20 engaging interviews conducted by Lori Palmer of Utah Valley State College with professionals from such fields as aviation, food services, banking, and environmental science motivate the key concepts from the text. Each vignette is accompanied by two problems written by Carolyn Hamilton of Utah Valley State College to test students' understanding of the underlying mathematical ideas and skills. The problems and answers are given on the CD-ROM; they are also reprinted in this manual with sufficient space to show student work.

Graphing Calculator Manual Written by Joan McCarter of Arizona State University, this manual covers several of the latest calculator models in more detail than do the Technology Tips in the text.