

S e c o n d E d i t i o n



Contemporary Precalculus

A Graphing Approach

Thomas W. Hungerford



Contemporary Precalculus

A Graphing Approach

Second Edition

Thomas W. Hungerford

CLEVELAND STATE UNIVERSITY



Saunders College Publishing

HARCOURT BRACE COLLEGE PUBLISHERS

Austin Philadelphia Fort Worth San Diego New York Orlando
San Antonio Toronto Montreal London Sydney Tokyo

Copyright © 1997, 1994 by Harcourt Brace & Company

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information storage and retrieval system, without permission in writing from the publisher.

Requests for permission to make copies of any part of the work should be mailed to: Permissions Department, Harcourt Brace & Company, 6277 Sea Harbor Drive, Orlando, Florida 32887-6777.

Text Typeface: Times Roman
Compositor: Progressive Information Technologies
Developmental Editor: Marc Sherman
Managing Editor: Carol Field
Project Editor: Bonnie Boehme
Copy Editor: Charlotte Nelson
Manager of Art and Design: Carol Bleistine
Art Director: Joan Wendt
Illustration Supervisor: Sue Kinney
Art and Design Coordinator: Kathleen Flanagan
Text Designer: Kathryn Needle
Cover Designer: Joan Wendt
Text Artwork: ST Associates
Director of EDP: Tim Frelick
Manager of Production: Joanne Cassetti
Production Manager: Alicia Jackson
Marketing Manager: Nick Agnew

Cover Credit: Neal Lavey/Phototake NYC

Printed in the United States of America

CONTEMPORARY PRECALCULUS: A GRAPHING APPROACH
Second Edition

ISBN 0-03-018544-0

Library of Congress Catalog Card Number: 95-072986

789012345 039 10 98765432

*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

Contemporary Precalculus: A Graphing Approach, Second Edition, is intended to provide the essential mathematical background needed in calculus for students who have had 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. The book enables students to become active participants in developing their understanding of mathematics, but avoids the very real danger of making technology an end in itself. We have done our best to present sound mathematics in an informal manner that stresses meaningful motivation, careful explanations, and numerous examples, with an ongoing focus on real-world problem solving.

As in the first edition, the emphasis is on developing the concepts that play a central role in calculus by exploring these ideas from graphical, numerical, and algebraic perspectives. With the assistance of technology, the interplay between these viewpoints can be fully exploited to give students insight into what is going on and the confidence to work with it on their own. Instructors can spend less time on “mechanics” and more on the underlying concepts. They can focus on the essentials, without getting bogged down in calculations that obscure the key ideas.

Changes in the Second Edition

When the first edition was written, the graphing calculator of choice was the TI-81 or comparable Casio and Sharp models.* By the time the book was published, the next generation of calculators, such as the TI-82, TI-85, and Sharp 9300, were just coming into widespread use. Now these calculators, together with the TI-83, HP-38 and Casio 9800, are the precalculus standard, with the even more powerful TI-92 just coming into wider use. Although these improvements in technology do not affect the mathematical concepts involved, they do make available a wider range of tools and change the procedures used in many cases, and thus the need for a technologically updated edition.

*Various HP models, such as the HP-48, were much more powerful, but were not as widely used at the precalculus level because they were perceived to be less user-friendly.

Users of the first edition have suggested a number of other changes that are now incorporated in the text.

Technology Assistance Instructors were happy that the first edition was not tied to a particular brand of graphing calculator, but also reported that many students failed to make full use of the capabilities of their calculators, often because they didn't realize what the calculators could do. Consequently, we have kept the discussions of technology in the body of the text as generic as possible, while adding two new features. *Technology Tips* in the margin offer advice on how to use specific graphing calculators. *Calculator Investigations* precede many of the exercise sets in the early sections of the book to encourage and enable students to become familiar with the capabilities and limitations of graphing and other technology. Both new features can be easily omitted by those who don't need them, but should provide significant assistance to others.

Program Appendix A small collection of useful programs has been included. Most of them are not needed by students who have state-of-the-art calculators, but will provide others with features that are not built into their calculators.

Exercises The majority of the exercises are retained, but ones that “didn't work” as teaching devices have been deleted or altered. Many new exercises, particularly applications, have been added.

Limits and Continuity Because very few instructors who adopted the first edition used this chapter, it is now published separately to save space. It is available at nominal cost to those who request it.

Instructor's Manual and Student Solutions Manual A new author has re-worked all solutions, which were then accuracy reviewed, in order to ensure the highest quality solutions manual.

In addition to these global changes, mathematical and pedagogical improvements have been made in various parts of the text, including the following.

Technology and Equations The discussion of equations in Section 1.5 has been expanded to include numerical as well as graphical solution methods. The applications that follow are now in two sections: Applications of Equations and Optimization Applications.

Secant Method An optional excursion that explains the secant method for solving equations has been added to Chapter 3.

Exponential Functions Section 5.2 now has a more complete presentation of exponential growth and decay.

Logarithmic Functions The emphasis on natural logarithms is retained, but common logarithms are introduced simultaneously with them in Section 5.3 because students seem to find them easier to understand.

Trigonometry The number and variety of applied exercises in Chapter 7 have been increased and approximately two dozen new figures have been added.

Systems of Equations The Gauss-Jordan method is now included in Section 11.2.

Mathematical and Pedagogical Features

The mathematical approaches to important topics used in the first 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.

All of the student-oriented pedagogical features of the first edition are included here.

Graphing Explorations Students are expected to participate actively in the development of concepts and examples by using graphing technology to complete many discussions in the text.

Warnings Students are alerted to common errors and misconceptions (both mathematical and technological) by clearly marked warning boxes.

Exercises Exercise sets proceed from routine calculation 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 different from what students may have seen before; a few of the *Thinkers* are quite challenging. Answers for all odd-numbered problems are given in the back of the book, and solutions for these problems are in the Student 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.

Supplements

The following chart summarizes the print and software supplements available to users of this text. A full description of each is given in the “To the Instructor” section on page xiv or the “To the Student” section on page xvii.

	<i>Print Ancillaries</i>	<i>Software</i>
<i>Instructors</i>	Instructor’s Manual Test Bank Graphing Calculator Manual Transparency Masters	F/C/P Graph (DOS, Mac, and Windows) EXAMaster+ Computerized Test Bank
<i>Students</i>	Student Solutions Manual Graphing Calculator Manual	F/C/P Graph (DOS, Mac, and Windows)

Acknowledgments

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

Deborah Adams, *Jacksonville University*
 Kelly Bach, *University of Kansas*
 Bettyann Daley, *University of Delaware*
 Betty Givan, *Eastern Kentucky University*
 William Grimes, *Central Missouri State University*
 Charles Laws, *Cleveland State Community College*
 Martha Lisle, *Prince George’s Community College*
 Ruth Meyering, *Grand Valley State University*
 Philip Montgomery, *University of Kansas*
 Roger Nelsen, *Lewis & Clark College*
 Ann Steen, *Santa Fe Community College*
 Hugo Sun, *California State University at Fresno*
 Bettie Truitt, *Black Hawk College*

Thanks also go to the following respondents to a graphing calculator survey:

Anne Brown, *Indiana University at South Bend*
 Bruce Hoelter, *Raritan Valley Community College*
 Marian Hukle, *University of Kansas*
 Sandra Johnson, *St. Cloud State University*
 John Khalilian, *University of Alabama*
 Jack Porter, *University of Kansas*
 Jan Rizzuti, *Central Washington University*
 Howard Rolf, *Baylor University*

I am grateful to the accuracy reviewers

Joan McCarter, *Arizona State University*
 Lauren Ricketts, *Normandale Community College*

who examined (and corrected where necessary) the examples and exercises; as well as checking the Student Solutions Manual. Their work has greatly improved the final product.

The text maintains its high level of accuracy due to the accuracy reviewers of the first edition:

John Khalilian, *University of Alabama*
 Lynn Kotrous, *Central Community College—Platt Campus*
 Seyed Pedram, *University of Alabama*

It is a pleasure to acknowledge the invaluable assistance of the Saunders staff, particularly Marc Sherman, Senior Developmental Editor, and Bonnie Boehme, Project Editor. Their fine work has made a difficult project seem easy.

The last word goes to my wife, Mary Alice, whose patience has been sorely tried during the past year. She has provided understanding and support when it was most needed, and I love her dearly.

Thomas W. Hungerford
 Cleveland, Ohio

To the Instructor

Every effort has been made to make this text as flexible as possible. With minor exceptions (usually exercises or occasional examples), the interdependence of chapters is given by the chart on the facing page. Each chapter begins with a **Roadmap** that indicates the interdependence of sections within the chapter.

As noted in the preface, the standard review of basic algebra is in the Algebra Review Appendix. This material, which is a prerequisite for the entire book, may be covered as Chapter 0 if necessary, or omitted by well-prepared classes.

A few sections are labeled as **Excursions**. Each Excursion is closely related to the section that precedes it and usually has that section as a prerequisite. No Excursion is a prerequisite for any other section of the text. With rare exceptions, each Excursion is a complete discussion with a full set of exercises. The “Excursion” label is designed solely to make syllabus planning easier and is *not* intended as any kind of value judgment on the topic in question.

The use of the **Graphing Explorations** in the text are discussed in the “To the Student” section on page xvii.

An optional final chapter on **Limits and Continuity** is published separately and available at nominal cost to schools that adopt the text. If you wish to include this material in your course, please contact your local sales representative.

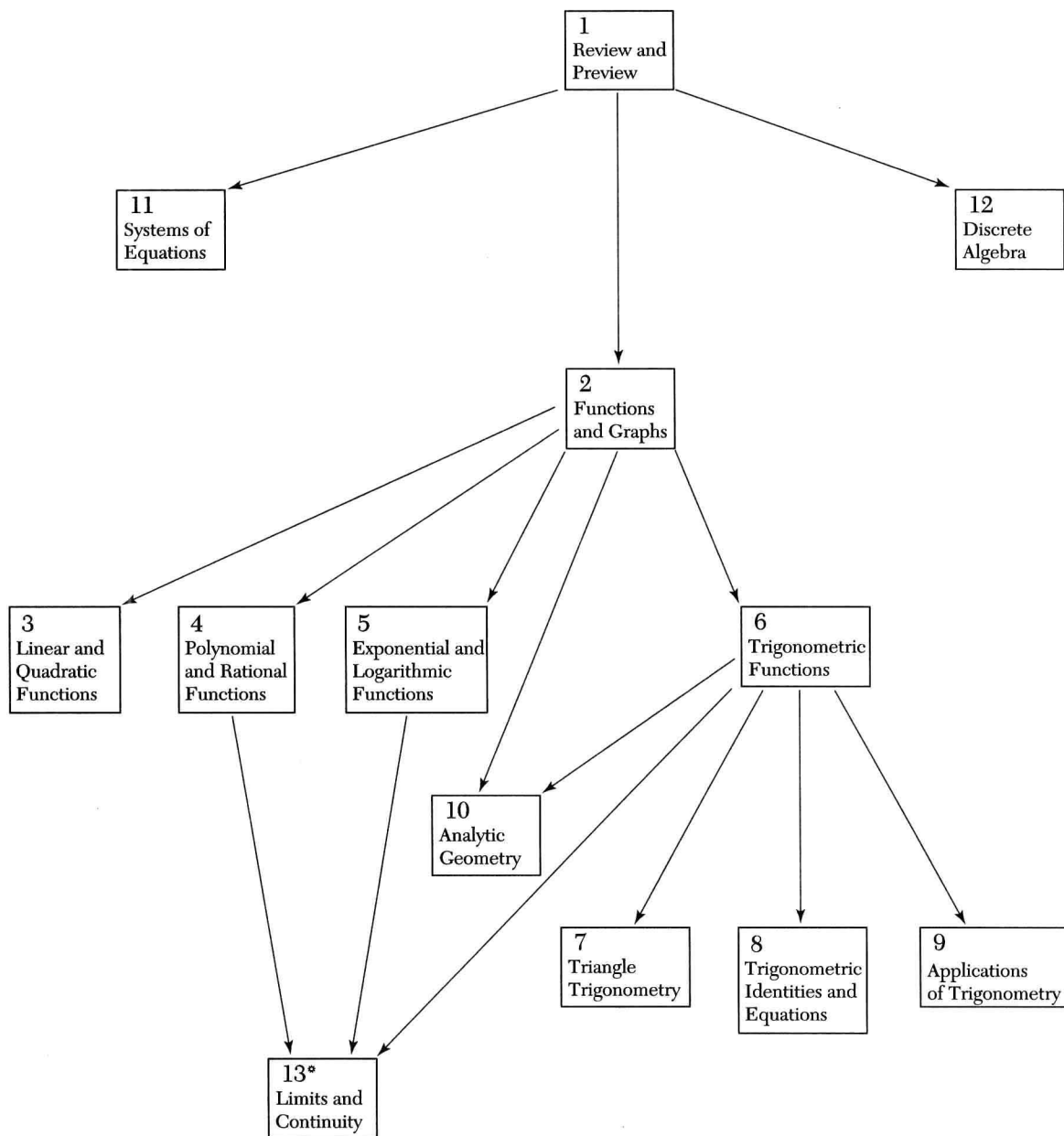
Supplements

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

Instructor’s Manual with Transparency Masters 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. Additionally, more than 60 transparency masters of important figures, theorems, and charts from the text are provided.

Test Bank Written by Bruce Hoelter of Raritan Valley Community College, this manual provides 2000 multiple choice and open-ended questions arranged in five forms per chapter, each form containing about 30 questions. Master answer sheets and a complete answer section are included.

Interdependence of Chapters



* Chapter 13 is published separately and is available at nominal cost to schools that adopt this text.

EXAMaster+™ Computerized Test Bank (IBM, Mac, and Windows versions) The computerized test bank contains all the test bank questions and allows instructors to prepare quizzes and examinations quickly and easily. Features include: (1) ability to convert multiple choice questions into short answer questions, (2) ability to enter and edit instructor's questions, (3) ability to create and administer a test via computer over a network or with floppies, whereby answers are scored and grades are transferred to an electronic gradebook, and (4) user-friendly printing capability to accommodate all printing platforms.

Graphing Calculator Supplement This supplement covers several major brands of the latest calculator models for problem solving in precalculus. It is written by Ron Marshall and Nicholas Norgaard of Western Carolina University.

F/C/P Graph software (IBM and Mac versions) Offered free to instructors and copyable upon adoption. This user-friendly, interactive software on Functions, Conics, and Parametric equations, written by George W. Bergeman of Northern Virginia Community College, allows students to build their graphing skills and explore precalculus topics in a self-paced, colorized format, and can be used in most instances in place of a graphing calculator. Computer lab exercises accompany the software. Special features include: a root-finder, a maxima-minima finder, ability to graph up to four functions simultaneously, and printing support.

The **Windows™** version of F/C/P Graph includes two features especially helpful to instructors who create handouts and exams, and for students doing projects or homework:

Users can print graphs and scale them to their size requirements.

Users can save graphs to bitmap files for import into their word processing programs.

Saunders College Publishing may provide complimentary instructional aids and supplements or supplement packages to those adopters qualified under our adoption policy. Please contact your sales representative for more information. If as an adopter or potential user you receive supplements you do not need, please return them to your sales representative or send them to

Attn: Returns Department
Troy Warehouse
465 South Lincoln Drive
Troy, MO 63379

To the Student

In order to use this text effectively you must have a graphing calculator or a computer equipped with appropriate graphing software (or both). (Free software is available from your instructor, as explained below.) In the text, the terms “calculator” and “graphing calculator” are used interchangeably. It is understood that, with obvious modifications, all discussions of calculators apply equally well to graphing software for computers.

The text is not written for a specific calculator, so some of the illustrations of calculator screens may not look exactly like yours. Furthermore, you may have to figure out the keystrokes needed to carry out particular procedures. To assist you in doing this, there are frequent **Technology Tips** in the margin. These Tips describe the proper menus or keys to be used on specific calculators that use standard algebraic notation (such as TI-81/82/83/85/92, HP-38, Casio 7700/8700/9800, and Sharp 9300).^{*} When the Tips are not sufficient, consult the instruction manual for your calculator.

Since many students are not aware of the full capabilities of their calculators, many of the early sections in this book contain **Calculator Investigations** (just before the exercise sets). These investigations will help you to become familiar with your calculator and to maximize the mathematical power it provides. Even if your instructor does not assign any of these investigations, you might want to look through them to be sure you are getting the most you can from your calculator.

The key to succeeding in this course is to 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. You have to take an active role, making use of all the resources at your disposal: your instructor, your fellow students, your calculator (and its instruction manual), and this book.

It’s no secret that many students use their math books only to find out what the homework problems are. If you are one of these, we strongly suggest that you change your ways. There is no way that 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 calculus unless you read the text fully

^{*}HP-48 users should consult the Graphing Calculator Supplement, which is described below, to adapt these tips to the Reverse Polish Notation used on that calculator.

and carefully. In particular, you should read the appropriate section of the text *before* beginning the exercises in that section.

You can't read a math book the way you read a novel or even a history book. You need pencil, paper, and your calculator at hand to work out the statements that you don't understand and to make notes on things to ask your fellow students and/or your instructor. One feature of this book will assist you to become such an interactive reader. The label **Graphing Exploration** indicates that you are to use your calculator as directed in order 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.

Finally, remember the words of the great Hillel: "The bashful do not learn." There is no such thing as a "dumb question" (assuming, of course, that you have read the book and your notes). Your instructor will welcome questions that arise from a serious effort on your part. In any case, your instructor is being paid (with your tuition money) to answer questions. So do yourself a favor and get your money's worth—ask questions.

Supplements

Students using *Contemporary Precalculus* may obtain the following software at no cost.

F/C/P Graph software (IBM, Windows, and Mac versions) is user-friendly, interactive software that can be used in most instances in place of a graphing calculator. Special features include: a root-finder, a maxima-minima finder, ability to graph up to four functions simultaneously, and printing support (so you can save your work). Your instructor has (or can obtain) this software, which you are free to copy.

Students may purchase the following supplements.

The **Student Solutions Manual**, written by Matt Foss of North Hennepin Community College, contains detailed solutions to all 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.

Graphing Calculator Supplement This supplement covers several major brands of the latest calculator models for problem solving in precalculus. It is written by Ron Marshall and Nicholas Norgaard of Western Carolina University.

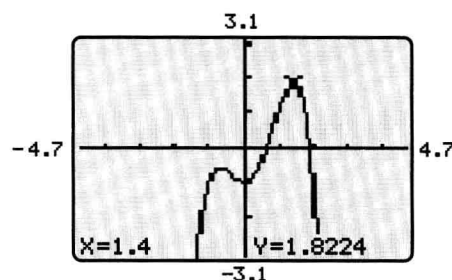
Contents

Preface	v
To the Instructor	xiv
To the Student	xvii

CHAPTER 1

Review and Technology Preview 1

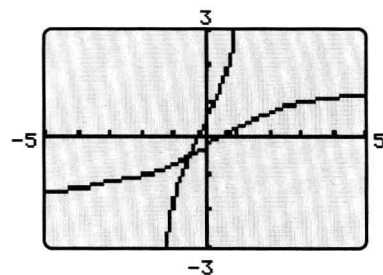
1.1	The Real Number System	1
1.1.A	<i>Excursion:</i> Decimal Representation of Real Numbers	12
1.2	Solving Equations Algebraically	15
1.2.A	<i>Excursion:</i> Absolute Value Equations	23
1.3	The Coordinate Plane	24
1.4	Graphs and Graphing Calculators	32
1.5	Solving Equations Numerically and Graphically	49
1.6	Applications of Equations	60
1.7	Optimization Applications	71
<i>Chapter Review</i>		80



CHAPTER 2

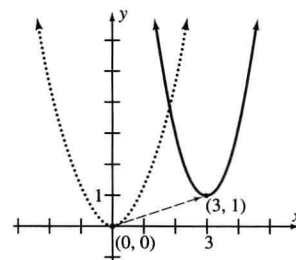
Functions and Graphs 86

2.1	Functions	86
2.2	Functional Notation	95
2.3	Graphs of Functions and Equations	105
2.4	Graph Reading	115
2.5	Graphs and Transformations	123
2.5.A	<i>Excursion:</i> Symmetry	133
2.6	Operations on Functions	139
2.7	Inverse Functions	148
<i>Chapter Review</i>		158

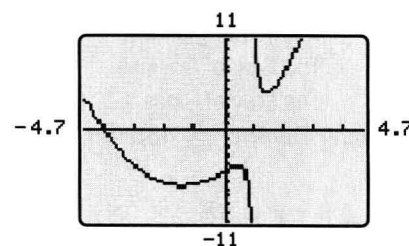


CHAPTER 3**Linear and Quadratic Functions 165**

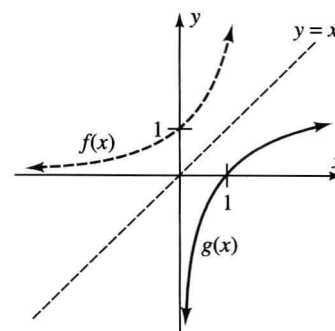
- 3.1 Lines and Linear Functions 165
 3.2 Rates of Change 179
 3.2.A *Excursion: The Secant Method* 191
 3.3 Quadratic Functions 196
Chapter Review 204

**CHAPTER 4****Polynomial and Rational Functions 209**

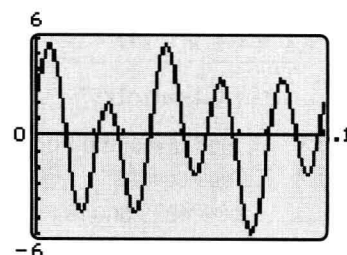
- 4.1 Polynomials and Polynomial Functions 209
 4.1.A *Excursion: Synthetic Division* 217
 4.2 Roots of Polynomials 220
 4.3 Graphs of Polynomial Functions 229
 4.4 Rational Functions 242
 4.4.A *Excursion: Other Rational Functions* 260
 4.5 Polynomial and Rational Inequalities 264
 4.5.A *Excursion: Absolute Value Inequalities* 274
 4.6 Complex Numbers 278
 4.7 Theory of Equations 285
Chapter Review 292

**CHAPTER 5****Exponential and Logarithmic Functions 299**

- 5.1 Radicals and Rational Exponents 299
 5.1.A *Excursion: Radical Equations* 306
 5.2 Exponential Functions 313
 5.2.A *Excursion: Compound Interest and the Number e* 326
 5.3 Common and Natural Logarithmic Functions 332
 5.3.A *Excursion: Logarithmic Functions to Other Bases* 344
 5.4 Algebraic Solutions of Exponential and Logarithmic Equations 351
Chapter Review 360

**CHAPTER 6****Trigonometric Functions 365**

- 6.1 Angles and Their Measurement 365
 6.2 The Sine, Cosine, and Tangent Functions 375
 6.3 Basic Graphs 383



6.4	Basic Identities	396
6.5	Alternate Descriptions and Special Values	402
6.6	Other Trigonometric Functions	412
6.7	Periodic Graphs and Simple Harmonic Motion	421
6.7.A	Excursion: Other Trigonometric Graphs	434
	Chapter Review	441

CHAPTER 7

Triangle Trigonometry 451

7.1	Right Triangle Trigonometry	451
7.2	The Law of Cosines	462
7.3	The Law of Sines	470
	Chapter Review	483

CHAPTER 8

Trigonometric Identities and Equations 486

8.1	Basic Identities and Proofs	486
8.2	Addition and Subtraction Identities	495
8.2.A	Excursion: Lines and Angles	504
8.3	Other Identities	508
8.4	Trigonometric Equations	516
8.5	Inverse Trigonometric Functions	528
	Chapter Review	537

CHAPTER 9

Applications of Trigonometry 542

9.1	The Complex Plane and Polar Form for Complex Numbers	542
9.2	DeMoivre's Theorem and n th Roots of Complex Numbers	549
9.3	Vectors in the Plane	557
9.4	The Dot Product	572
	Chapter Review	583

CHAPTER 10

Analytic Geometry 587

10.1	Plane Curves and Parametric Equations	587
10.2	Conic Sections	602
10.3	Translations and Rotations of Conics	616

