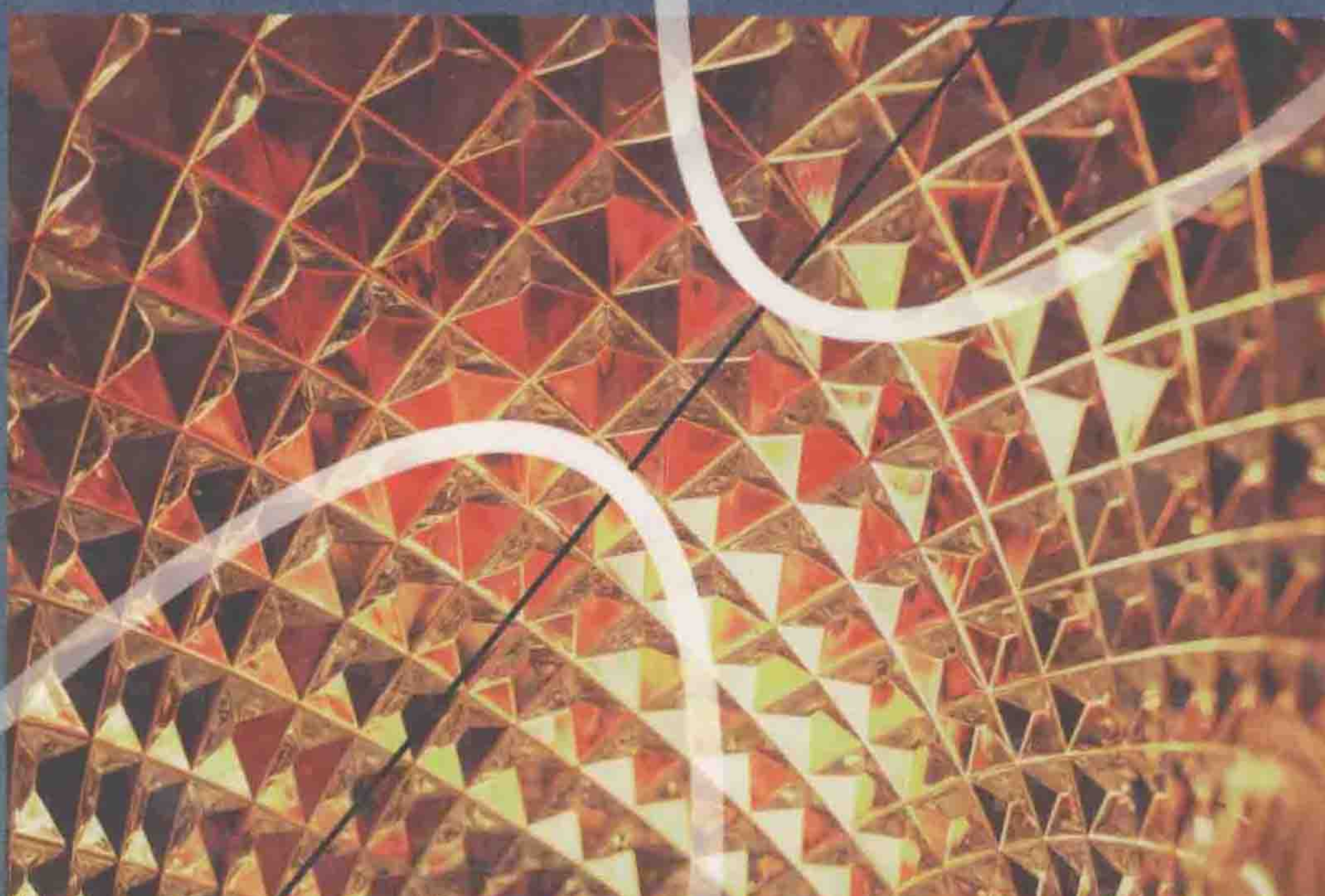
Precalculus PLUS

Ronald D. Ferguson



Precalculus Plus

RONALD D. FERGUSON
San Antonio College

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DEDICATION

For your patience, love and understanding . . .
To Layne Ferguson, Julie Ferguson, and Lara Ferguson
Thanks and love.

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PREFACE

PreCalculus Plus is for students preparing for calculus or introductory computer science. The text assumes a prerequisite of the equivalent of two years of high school algebra and includes all the standard topics of precalculus mathematics *plus* a few extras. Among these extras are extensive use of graphics and technology, previews of calculus concepts, and discussions of numerical methods from discrete mathematics.

PHILOSOPHY

A textbook is the consequence of many forces. Philosophy influences the presentation of topics as surely as tradition and market considerations. My goal in writing *PreCalculus Plus* was to implement the consensus topics of precalculus mathematics within the following framework:

A text should not break topics into isolated modules. This text endeavors to tie a current topic to previous topics. The connections usually take the form of some thematic element such as transformations.

Student comprehension improves when a concept is presented in more than one context. Although the principal discussion of a concept may occupy a single location in the text, the text explores many topics thematically. For example, linear models occur frequently throughout the text, as do quadratic functions, transformations, and the composition of functions.

Although Chapter 0 reviews prerequisite topics and much of Chapter 1 also may be review material, I believe a student benefits more from applying old skills in the context of new problems and concepts. For that reason, many exercises require the student to use prior concepts and skills.

Mathematics is a tool for modeling real-world situations. This text emphasizes that information can be expressed in numerous ways, including different algebraic forms, visually in the form of graphs, and even as a recursive process. As representations of information, each of these forms models the information. The text also discusses the limitations of models.

The transformation of information into different forms provides new insight into the information. For this reason a major theme of the text is transformations. From this perspective, the text presents algebra as a method for rewriting information. Analysis converts information from numerical to geometric representations and vice versa. Abstraction and idealization transform real-world problems into models. Technology provides a powerful tool for transforming the presentation of data.

The evolution of mathematical thought provides a model to improve student understanding of concepts. Etymology and historical anecdotes reveal mathematics as a human quest for knowledge rather than the arcane incantations of mathematical priests.

Concept development should exploit technology without inducing dependence on technology. Dependence should be avoided in two ways. First, the text should not predicate the development of a topic solely on an appeal to technology. Although calculator graphics are compelling, we should appeal to students' imaginations as well as their eyes. As a result, the text often uses the flaws in calculator graphics rather than the successes to illuminate a topic.

Second, the student must not become dependent on technology. The graphing calculator should be the student's tool, not the remote control to the student's brain. The text encourages, but does not require, that the student have graphing technology. Most examples include detailed graphs for the student without technology. Examples demonstrate methods for visualizing data that do not require technology, as well as examples that promote technology. Indeed, the text encourages the student to critically examine technology by providing assignments to convert graphs to charts, requesting annotations of graphs, and including examples of misrepresentation by technology.

A student without access to a graphing calculator or computer is given visual experience from the textbook. To improve student visualization, the text makes heavy use of computer-generated graphics. Be warned—exercises emphasizing the exploration of graphs are quite tedious without technology. A calculator icon  marks these technology-intensive exercises.

The technological media must not become the message. In today's society, the availability of technology is commonplace. We should treat technology as if it were a compass, ruler, graph paper, or any other tool. This book tries not to let the student think that technology, rather than mathematics, is the goal of a discussion.

Technology is a valuable tool. On the train ride to knowledge, technology provides a window to view a concept. The train has other windows and multiple views. Without doubt, a good window seat can enhance almost any train ride. No matter what view the student finds most appealing, graphing technology is not the whole ride. Indeed, the text points out the dangers of applying a technological tool without first having a firm theoretical base.

As the computer provides a model for human thought, technology provides pedagogical models for learning and teaching. This text was designed to use technological approaches that offer insight to those without technology. For example, the text uses window views of computer screens for graphs. Other examples include transformations as a visual model for the composition of functions. Thus, the presentation should mesh nicely with such technological constructs as scrolling and setting ranges while serving equally well for students without calculators.

STRUCTURE OF THE TEXT

OUTLINE OF TOPICS

Chapter 1 reviews graphing techniques and introduces graphing calculators. The chapter presents graphs of lines, circles, and parabolas for calculator practice and to foreshadow functions in Chapter 2. Chapter 2 uses a window view for graphs of functions. Moreover, the chapter categorizes functions in terms of common properties such as increasing, decreasing, odd or even and so on. In addition, the algebra of functions helps prepare for the introduction of polynomials in Chapter 4. Compositions introduce the theme of transformations. Inverse functions set up logarithms in Chapter 6.

Chapter 3 introduces approximation methods, analysis of graphs, and graphical solutions of inequalities by examining familiar linear, quadratic, and absolute value functions. The chapter also introduces tracing functions, continued fractions, and fixed-point iteration. Subsequent chapters revisit these techniques.

Chapter 4 extends linear and quadratic functions to polynomials. The comparison of polynomials to integers leads to the introduction of rational and algebraic functions in Chapter 5. Chapter 5 reemphasizes earlier themes such as domain, continuity, and asymptotes as graphical aids.

The transcendental functions introduced in Chapter 6 develop from the natural base e. As a result, the development more closely resembles the approach of calculus texts rather than the arrangement usually found in a precalculus text. The chapter discusses the machine representation of a finite-precision decimal using the mantissa and characteristic. In addition, the concept of logarithmic transformations extends the theme of transformations.

Chapter 7 uses angular and linear velocity to introduce the use of radian measure. Early in chapter 7, the connection between angles of rotation and triangles is made. Hence, while the text emphasizes the unit circle principles, classic triangle trigonometry is interwoven in the development of concepts. Based on the unit circle, with occasional applications of technology, the chapter gives an early introduction to the graphs of circular functions. In addition, transformations tie the analysis of graphs to the composition of functions. Applications of circular functions include the modeling of wave forms. To take advantage of technology, graphical interpretations are used to teach the concepts of identities and conditional equations.

Chapter 8 develops the solution of right triangles and general triangles. The solution of conditional equations leads to inverse trigonometric equations. Other applications include polar coordinates, two-dimensional vectors, and complex numbers.

Chapter 9 presents classic analytical geometry of conic sections, culminating in the rotation of conic sections using trigonometric functions. The rotation of conics provides an additional example of transformations. Chapter 10 develops systems of linear and nonlinear equations and systems of inequalities. The linear systems of Chapter 10 set up the development of matrices and determinants in Chapter 11. In keeping with mathematical history and a theme of the text, transformations provide the definition for the multiplication of matrices.

Finally, Chapter 12 presents the discrete mathematics topics most commonly found in precalculus texts: sequences, series, the binomial theorem, and so on. Infinite-series examples explain the difficulties of representing infinite decimals in a finite-precision machine. As the last chapter, Chapter 12 often ties the last knot of a new concept to previous topics. For example, the discussion of formal recursion in the form of finite mathematical induction inspires a recursive definition for a polynomial.

Structure of the Chapters

See the Summary of Features on page xxiii for specific examples of many of the following features.

Quotes

Most sections begin with a quotation that reflects the nature of topics in the section, an historical insight, or a comment on the value of mathematics. These quotations affirm that humans are the source of our mathematical heritage.

Sidebars

In the margins of the text, a sidebar provides a mathematical note for student enrichment. Most sidebars fall into one or more of the following categories.

Etymological. Some sidebars trace the historical origin of a word. This etymology gives students insight into the meaning of a word and into the evolution of the concept the word represents.

Historical. Historical notes provide a cultural heritage for mathematics. The evolution of mathematical thought may be more provocative than a simple statement of a modern view. Primary historical references in this book include *An Introduction to the History of Mathematics* by Howard Eves and Morris Kline's *Mathematical Thought from Ancient to Modern Times*.

Anecdotal. Anecdotal sidebars consist of fictional dialogues to provide interactive student insight into a concept. Reading a fictional dialogue may even encourage students to discuss mathematics among themselves or with their instructor.

Theorems and Definitions

The text highlights theorems and definitions. I do not expect students to become theorem-proving machines. However, reading, digesting, applying, or even formulating theorems and definitions encourages the thought process of students.

Exposition

The exposition that is provided is conversational. The job of exposition is to introduce and explain. The mode of exposition may vary from simple declarations to exploratory queries. Sometimes the student is led by examples to a theorem or definition, so that the formal statement of the concept summarizes the process. At other times, a definition or theorem comes first so that the student can learn to read and interpret the principle before applying the concept to examples. While sentence structure and diction is not usually complex, developing students' thinking skills sometimes requires developing their vocabulary.

Examples/Illustrations

Much of the effectiveness of this text is in the use of Examples.

An Example consists of a series of related illustrations used to develop a concept. Most examples include a label identifying the concept developed. Clearly marked solutions and answers are detailed in each illustration. Examples often parallel exercises at the end of a section.

Applications

Applications include a diversity of problems from fields such as engineering, biology, medicine, astronomy, architecture, and statistics. Applications offer opportunities to create mathematical models without too much distraction by artificial stories. Throughout the text, the use of numerical methods and finite precision decimals helps the student distinguish between exact representations and approximations. These discrete topics should benefit students using technology and students planning to study engineering or computer science.

Figures

For accurate representation, I generated figures for the text using *Graph-Windows* technology. The graphics were then imported into Aldus FreeHand for color enhancement and annotations. The annotations improve the clarity of the data.

Similarly, graphing exercises ask students to annotate the graphs they produce. This is especially important for graphical behavior that is poorly represented in a calculator display. Moreover, the student must then assume responsibility to do more than simply push a button and see a graph.

Technology

As more students acquire graphing calculators, it becomes more difficult to demand a specific brand and model for a class to use. If a student already has a graphing calculator, asking him or her to buy another for class uniformity is not likely to endear an instructor to the students. For that reason, graphing calculator examples are generic, in the sense that the text emphasizes the similarities among graphing calculators. Students using technology are reminded to set the window limits, enter a function, mind the mode, and execute the graph, zooming or scrolling as necessary. However, from time to time, some examples detail specific key strokes for the following calculators:

Casio fx7700-G

TI-81, TI-82, TI-85

Sharp EL9200/9300

There are a number of reasons for occasionally providing specific key strokes. First, it gives a student with one of these calculators quick access to an example without having to search a manual. It provides close comparison of key strokes to reinforce the similarities among calculators. Finally, it may inspire a student without a calculator to realize that a calculator is not only fast, but it is also easy to use. The last reason is important in a class that does not require calculators but does encourage their use.

Although several fine computer programs are available for producing graphs, for example Mathematica, Derive (see Available Supplements), MathCad, MicroCalc, etc., these programs are massive. I leave the discussion of these packages to the instructor and a user's manual. The computer graphics package discussed in this text is *GraphWindows*. Adopters of the textbook receive a limited license for the use of *GraphWindows*.

On the basis of ten years of experimenting with computer graphics to demonstrate concepts in precalculus and calculus, I wrote *GraphWindows* with several goals in mind. First among these goals was a gradual learning curve. Students should not have to learn specialized notation to store functions. Standard activities such as selecting a window, zooming, scrolling, and graphing should be intuitive. The display should be in color, so that functions are easy to identify. Compositions of user-defined functions should be natural to encourage experimentation with transformations.

Because EGA/VGA displays have higher resolution than current graphing calculators, *GraphWindows* provides sharper, more colorful classroom demonstrations. In particular, the graphs of three or more inequalities are much clearer in the blended colors produced by *GraphWindows* than on a graphing calculator. *GraphWindows* also supports polar and parametric representations.

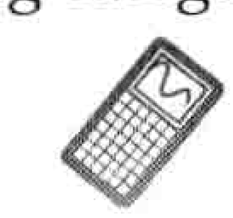
Because the goal for *GraphWindows* is to allow a student to explore the two-dimensional graphs, the program is relatively small and should run on many older IBM compatible machines. If your department has a microcomputer lab and is reluctant to require that all students buy a graphing calculator, *GraphWindows* in a computer lab will allow students to experiment with graphing technology. The text includes examples of graphing using *GraphWindows* version 2.02. However, for details on the use of the latest version of *GraphWindows*, consult the *GraphWindows* user's manual.

EXERCISES

The exercises at the end of each section provide practice of concepts introduced in that section and review of related concepts. Red exercise numbers identify application exercises. Asterisks (*) mark those exercises requiring extra care. Exercise sets consist of parallel odd and even exercises. As a result, an instructor can assign all even, all odd, or perhaps multiples of three with the assurance that a student receives a full exposure to the concepts of the section. Appendix B provides answers to selected odd exercises. The problem sets are graded by level of difficulty in the sense that more difficult problems appear toward the end of each set of instructions, and in general toward the end of the exercises. While the exercises encourage a student to use technology, lack of a calculator usually will not keep a student from completing the exercises. You must take more care in making assignments from the problem sets.

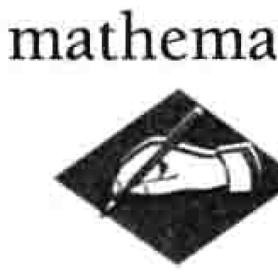
PROBLEM SETS

Problem sets appear at the end of most sections. Problem sets consists of more challenging problems than in the exercises. As with the exercises, a red problem number identifies an application problem. Although the problem sets usually have parallel odd and even problems, such is not always the case. Often a sequence of several problems is necessary to complete the development of a concept. Depending on the section, many problem sets fall into one or more of the following categories.

TECHNOLOGY.  A graphing calculator icon marks problems that are difficult to do without technology. These problems may alternately be labeled as Problems for Technology. In general, technology problems overlap with problems in the Confirmation and Exploration categories.

CONFIRMATION. Confirmation problems offer the student experiments with graphing technology that reinforce concepts from the section just completed. Based on these experiments, the confirmation problems may ask the student to summarize the concept.

EXPLORATION.  A binocular icon marks Exploration problems. Many Exploration problems preview concepts to be introduced in the next section. Some Exploration problems overlap the Preview of Calculus problems. Typically, these problems ask a student to make conjectures based on a sequence of graphic patterns. Usually the student must summarize, describe the new concept, or formulate a definition. Many of these summary problems overlap the Writing mathematics category.

WRITING MATHEMATICS.  A writing hand icon often labels a requirement to verbalize a concept. This task takes the form of formulating a definition, summarizing a result, or describing a concept. As a result, the problem encourages the student to look for patterns, make inferences, test conclusions, and communicate by writing. Constructing sentences to express what you have learned is a valuable opportunity to organize your thoughts.

Closer Looks. A magnifying glass icon marks Closer Look problems. These problems explore concepts in greater detail or develop theory related to topics in the section. Many are more theoretical than usual.

Preview of Calculus. Preview of Calculus problems give students a chance to connect precalculus concepts and techniques to elements of the calculus. Like Closer Look problems they are intended to challenge better students. The problems in Preview of Calculus include calculating slopes of secant lines, intuitive tangent lines, slopes of tangents to functions, and areas under curves. A blue-green problem number identifies these problems.

Enrichment Topics. Enrichment topics include concepts not normally found in precalculus texts. These topics include continued fractions, power series, radix notation, and finite-precision decimals. Other problems coach the student through the development of Cardan's solution of a cubic equation, the derivation of the quadratic formula using transformations, or the derivation of Hero's formula.

Choose carefully in making assignments from the problem sets.

Section Summary

Every section includes a summary of introduced topics. Depending on time constraints, you may wish to spend more than one lecture on some sections. For example, you could follow an introductory lecture and assignment in the exercises with a second lecture and assignment in the problem sets. Sections are organized by convenient divisions for topics, not for presorted one hour lectures. The length of a section does not necessarily correspond to its importance. However, few sections demand more than one lecture.

Key Words and Concepts

The end of each chapter lists key words and concepts to facilitate student review.

Chapter Summary

Chapter summaries give concise review of major topics. These summaries repeat the major concepts from section summaries for easy reference.

Review Exercises

Review exercises appear at the end of each chapter, keyed to the section where they were introduced. These exercises provide concise samples of exercises found within each section of a chapter. When a student encounters difficulty in reviewing these exercises, the section reference allows for quick access to the original material.

Sidelights

A sidelight appears at the end of each chapter. Sidelights are usually longer excursions into a historical reference, a short biography, or a discussion of the evolution of some other mathematical concept.

Chapter Tests

A chapter test appears at the end of each chapter. Chapter tests are for student practice. Most instructors will not cover every chapter in a book nor give a test at the end of each chapter. For that reason, I made only a modest attempt at equalizing the size of chapters. I thought it was more important to have chapters meaningfully group topics. For this reason, a trigonometry chapter may be long whereas a chapter on algebraic functions is short.

Available Supplements

Solution Manuals

The *Instructor's Solution Manual* contains solutions to even-numbered problems in the text. The *Student's Solution Manual* contains solutions to the odd-numbered problems. Sharon Edgmon of Bakersfield College prepared the solutions to all problems. At least one independent accuracy checker checked each solution.

Test Bank

Norma James, New Mexico State University, wrote the Test Bank, which consists of four sample tests per chapter, two of which use multiple choice questions and two of which use open-ended questions.

Graphing Calculator Manual

Samuel A. Lynch, Southwest Missouri State, prepared the *Graphing Calculator Manual* to accompany *PreCalculus Plus*. The manual introduces the use of the TI-81 calculator and illustrates commands and key strokes for the TI-81, often using examples from *PreCalculus Plus*. The manual points out differences between the TI-81 and TI-82. An appendix includes keystroke information for the Casio fx7700-G. The tutorial follows the same order of topics as *PreCalculus Plus* and includes graphing calculator exercises and answers.

Exploring Precalculus with DERIVE

Exploring Precalculus with DERIVE is a workbook consisting of 28 explorations created by E. Hodes, P. Yuhn, and R.M. Mallen of Santa Barbara City College. Elizabeth Hodes edited the workbook, which coaches students through 28 precalculus experiments using DERIVE software (DERIVE, A Mathematical Assistant by Soft Warehouse, Inc.). Each exploration includes questions requiring the student to formulate and write conclusions about the exploration.

User's Manual

Designed as a reference for instructors, the *User's Manual for PreCalculus Plus* by Ronald D. Ferguson contains suggested course syllabi and lists of dependencies. To ease homework assignment the manual tabulates exercise page numbers with notes on the nature of the problems. For many sections, the manual suggests classroom technology demonstrations. These demonstrations may use technology for motivation or caution against difficulties faced in technology. The suggested demonstrations assume the instructor has access to graphing technology appropriate for classroom demonstrations. Some sections include a rationale for the approach to a concept. Rationales are most likely if the development of a topic differs from the standard treatment. Some rationales tie the new concept to a previous topic or foreshadow a topic developed in later sections. Some sections offer alternative approaches to a topic or particular cautions about an approach.

GraphWindows

GraphWindows, written by Ronald D. Ferguson, is available to book adopters. *GraphWindows* creates a gradual learning curve for technology by allowing students to enter formulas for functions much as they appear in textbooks. The program handles function composition, tracing, scrolling, and zooming in a natural manner to allow the student to concentrate on mathematics rather than technology. The screen design resembles a graphing calculator but takes advantage of the computer keyboard. The program operates in color under EGA/VGA on most IBM-compatible PCs.

Acknowledgments

Reviewers

I want to thank the following reviewers. In some cases, one reviewer's suggestion may conflict with another's. My job was to reconcile a multitude of suggestions. Therefore, where the text succeeds, much credit goes to the reviewers. Where it fails, I must blame myself.

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(Reviewers of *GraphWindows* software)
Iris B. Fetta, Clemson University
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William A. Rundberg, College of San Mateo
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Production Staff

Finally, thanks to the production people at West, the copy editors, artists, and designers. And to Tom Modl, production editor, who kept it going and put it all together.

Appeal for Suggestions and Comments

Textbooks evolve. This book is quite different from my original manuscript. Indeed, the changing target of technology has dictated constant revision and refinement during the design. Because production takes about a year, I rewrote not only according to what was current but toward what I imagined would be standard in a year. When the target moves, you must resight and hope you don't follow too much or lead too little. This is not a complaint or an excuse. I hope that the target will continue to move. Changing technology stimulates innovative teaching methods. So even as we go to press, I am thinking about revision. I would appreciate your comments. Please write. No text can be all things to all people. But I promise to consider every suggestion carefully and use it if I can.

Ronald D. Ferguson
San Antonio College

SUMMARY OF FEATURES WITH SELECTED EXAMPLES

This list contains samples only and is not intended as a comprehensive index of every example to a feature.

Feature	Description	Example	Location
Sidebars			
Etymological	The sidebars show the evolution of mathematical words and concepts.	"Pair"	Ch. 1-3
		Parameters	Ch. 3-1
		Quadratic	Ch. 3-2
		Logarithm	Ch. 6-2
		Mantissa	Ch. 6-3
		Sine	Ch. 7-2
Historical	This feature briefly explains the History or source of a topic. Alternative views and asides are also presented.	Pythagoras	Ch. 1-1
		Concavity	Ch. 1-5
		Equality	Ch. 2-1
		Absolute	Ch. 3-6
		Calculus	Ch. 4-2
		Root	Ch. 5-2
		e	Ch. 6-1
		Degree	Ch. 7-1
		Tangent & secant	Ch. 7-2
		Cardan	Ch. 8-7
		Transform	Ch. 9-5

Feature	Description	Example	Location
Applications	These problems are identified by a red problem number. Real world applications are found in Examples, Exercises, and Problem Sets.	Medicine	Ex. 3-1 #41
		Physics	Ex. 3-1 #44
		Windmills, Pendulums, & Business	Examp. 3-4
		Projectiles	P.S. 3-2 #1
		Torricelli	P.S. 3-2 #5
		Statistics	P.S. 3-2 #4
		Music	P.S. 3-2 #6
		Approximation	P.S. 3-3
		Precision	Ch. 3-7
		Radix	Ch. 4-1
		Half-life & biology	Examp. 6-1
		Inflation & Music	Ex. 6-3 #55
			Ex. 6-3 #57
		Nautical mile	P.S. 7-1
		Wave forms	Ch. 7-4
		Astronomy	Ex. 8-2 #87
		Astronomy	Ex. 8-4 #46
		Electronics	Ex. 8-4 #49
		Medic: ESL	Ch. 9-1
		Listening Stat	P.S. 9-4
		Electronics	Ex. 10-1 #34
		Economics	Ex. 10-1 #39
		Aspect ratio	Ex. 10-2 #35
Exercises	Parallel Odd and Even Exercises are designed to provide practice for topics in a section. Answers to selected Odd exercises appear in Appendix B. An instructor may assign all even, all odd, or multiples of three and still cover all topics in a chapter.	All Exercise Sets	See end of any section. E.g. Ch. 2-1 or Ch. 4-2, etc.
Problem Sets	Go beyond drill and practice of concepts. Included are the following categories.	All Problem Sets	See end of each section.