# Precalculus Functions and Graphs

A Graphing Approach

Larson
Hostetler
Edwards

SECOND EDITION

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# Preface

*Precalculus Functions and Graphs: A Graphing Approach,* Second Edition, is the premier text for a reform-oriented course. Designed to build a strong foundation in precalculus, the text encourages students to develop a firm grasp of the underlying mathematical concepts while using algebra as a tool for solving real-life problems. The comprehensive text presentation invites discovery and exploration, while the integrated technology and consistent problem-solving strategies help the student develop strong precalculus skills.

## Precalculus Reform

The precalculus course has changed over the past few years in response to the growing discussion of reform in mathematics education. Generally speaking, these changes have focused on the following areas: technology, real-life applications, problem-solving, and communicating about mathematics. The Second Edition embodies the spirit of these reform ideals without compromising the mathematical integrity of the course presentation. All text elements from the previous edition were considered for revision and many new examples, exercises, and applications were added.

**Technology** Graphing technology is consistently incorporated throughout the Second Edition. The visualization and exploration capabilities of technology encourage the student to participate actively in the learning process, to develop their intuitive understanding of mathematical concepts, and to solve problems using actual data. Thus, students learn how algebra functions as a modeling language for real-life problems. Technology is used as a tool, drawn into the discussion whenever it offers a useful perspective on the topic at hand. For example, the power of graphing technology may be used to guide the students through thought-provoking explorations or to show alternative problem-solving techniques. Where appropriate, situations in which the results obtained through the use of technology may be misleading are also noted.

The Second Edition assumes that the student will use a graphing calculator on a daily basis in the course. Integrated throughout the text at point of use are many opportunities for investigation using technology (e.g., see page 103) and exercises that require the use of a graphing utility (e.g., see page 227). The text also carefully shows how to use graphing technology to best advantage (e.g., see page 217).

Whenever possible, references to graphing technology are generic. In a few cases, however, the text includes programs that will enable the student to investigate particular mathematical concepts (e.g., see page 115). Comparable programs for a wide variety of Texas Instruments, Casio, Sharp, and Hewlett-

Packard graphing calculators—including the most current models—are given in the appendix.

To accommodate a variety of teaching and learning styles, *Precalculus Functions and Graphs: A Graphing Approach,* Second Edition, is also available in a multimedia, CD-ROM format. *Interactive Precalculus Functions and Graphs: A Graphing Approach; A Self-Guided Study Companion* offers students a variety of additional tutorial assistance, including examples and exercises with detailed solutions; pre-, post-, and self-tests with answers; and *TI-82* and *TI-83* graphing calculator emulators. (See pages xviii–xx for more detailed information.)

**Real-Life Applications** To emphasize for students the connection between mathematical concepts and real-world situations, up-to-date, real-life applications are integrated throughout the text. These applications appear as chapter introductions with related exercises (e.g., see pages 237 and 280), examples (e.g., see page 5), exercises (e.g., see page 293), Group Activities (e.g., see page 276), and Chapter Projects (e.g., see page 307).

Students have many opportunities to collect and interpret data, to make conjectures, and to construct mathematical models in the examples, exercises, Group Activities, and Chapter Projects. Students work on modeling problems with experimental and theoretical probabilities (e.g., see page 723), use mathematical models to make predictions or draw conclusions from real data (e.g., see page 149), compare models (e.g., see page 230), and apply curve-fitting techniques to create their own models from data (e.g., see page 144). In the process, the Second Edition gives students many more opportunities to use charts, tables, scatter plots, and graphs to summarize, analyze, and interpret data.

**Problem Solving** The primary goal of any mathematics textbook is to encourage students to become competent and confident problem solvers. Many aspects of this revision focused on this goal—including the addition of new features such as Chapter Projects, Explorations, and Group Activities, as well as extensive and careful revision of the examples and exercise sets. Students are asked to use numerical, graphical, and algebraic techniques, and the use of graphing technology as a problem-solving tool is encouraged as appropriate (e.g., see page 155). Throughout, students are encouraged to follow a consistent approach to solving applied problems: Construct a verbal model, label terms, construct an algebraic model, solve the problem using the model, and check the answer in the original statement of the problem.

Like the previous edition, the Second Edition has an abundance of exercises that are designed to develop skills. The text also includes many other types of exercises that offer students the opportunity to refine their problem-solving skills, such as exercises that require interpretations (e.g., see page 251), those having many correct answers (e.g., see page 210), and multipart exercises designed to lead the student through problem-solving strategies (e.g., see page 230).

**Communicating about Mathematics** Each section in the Second Edition ends with a Group Activity. Designed to be completed in class or as homework assignments, the Group Activities give students the opportunity to work cooperatively as they think, talk, and write about mathematics. Students' understanding is reinforced through interpretation of mathematical concepts and results (e.g., see page 226), problem posing and error analysis (e.g., see page 201), and constructing mathematical models, tables and graphs (e.g., see page 258).

Making connections between algebra and real-world situations also helps students understand the underlying theory. Other connections are emphasized in this text as well, including those to probability (e.g., see Chapter 9), geometry (e.g., see page 397), and statistics (see Chapter 9).

## Improved Coverage

As a result of user requests Chapter P, Prerequisites, now begins with an introduction to the Cartesian plane and covers solving equations and inequalities both algebraically and graphically. All or part of this review material may be covered or omitted, offering greater flexibility in designing the course syllabus.

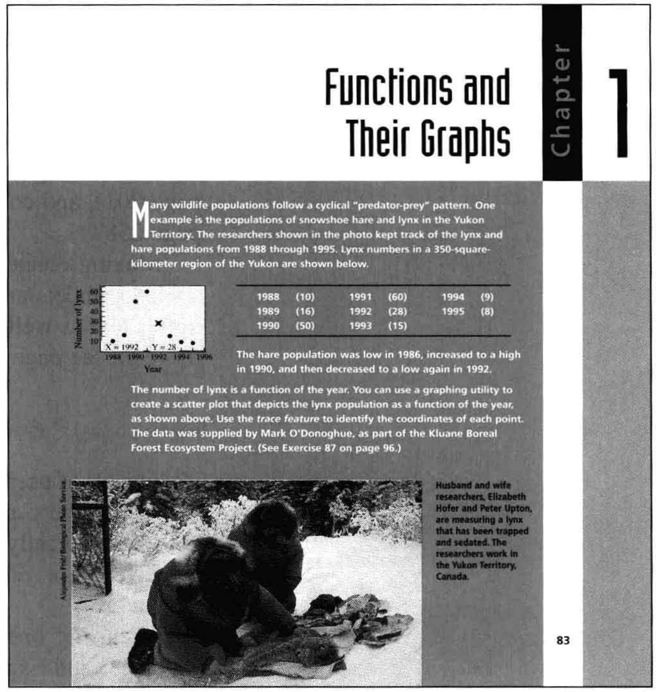
Occurring one chapter earlier are Polynomials and Rational Functions in Chapter 3 and Exponential and Logarithmic Functions in Chapter 4. The chapters covering trigonometry have been expanded to three chapters. Chapter 6 now includes Vectors in the Plane and Vectors and Dot Products previously covered in Chapter 11 of the first edition.

In keeping with the emphasis on real-life applications, sections titled Exploring Data are found throughout the text and include Representing Data Graphically, Linear Models and Scatter Plots, Nonlinear Models, Measures of Central Tendency, and Measures of Dispersion.

## Features of the Second Edition

**Chapter Opener** Each chapter opens with a look at a real-life application. Real data is presented using graphical, numerical, and algebraic techniques.

**Theorems, Definitions, and Guidelines** All of the important rules, formulas, theorems, guidelines, properties, definitions, and summaries are highlighted for emphasis. Each is also titled for easy reference.



Chapter 1

# Functions and Their Graphs

Many wildlife populations follow a cyclical "predator-prey" pattern. One example is the populations of snowshoe hare and lynx in the Yukon Territory. The researchers shown in the photo kept track of the lynx and hare populations from 1988 through 1995. Lynx numbers in a 350-square-kilometer region of the Yukon are shown below.

| | | | | | |
|---|---|---|---|---|---|
| 1988 | (10) | 1991 | (60) | 1994 | (9) |
| 1989 | (16) | 1992 | (28) | 1995 | (8) |
| 1990 | (50) | 1993 | (15) | | |

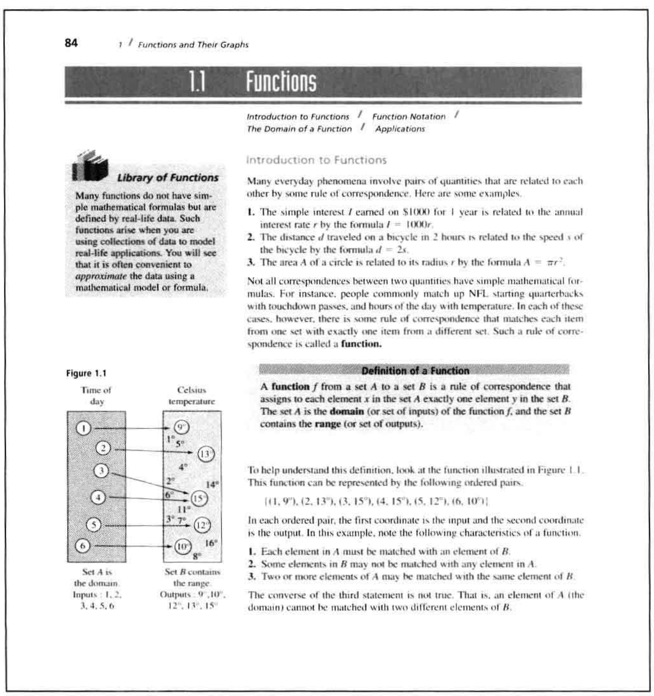


The hare population was low in 1986, increased to a high in 1990, and then decreased to a low again in 1992.

The number of lynx is a function of the year. You can use a graphing utility to create a scatter plot that depicts the lynx population as a function of the year, as shown above. Use the *trace feature* to identify the coordinates of each point. The data was supplied by Mark O'Donoghue, as part of the Kluane Boreal Forest Ecosystem Project. (See Exercise 87 on page 96.)

Husband and wife researchers, Elizabeth Hofer and Peter Upton, are measuring a lynx that has been trapped and sedated. The researchers work in the Yukon Territory, Canada.

83



84 1 / *Functions and Their Graphs*

## 1.1 Functions

*Introduction to Functions / Function Notation / The Domain of a Function / Applications*

**Library of Functions**

Many functions do not have simple mathematical formulas but are defined by real-life data. Such functions arise when you are using collections of data to model real-life applications. You will see that it is often convenient to *approximate* the data using a mathematical model or formula.

### Introduction to Functions

Many everyday phenomena involve pairs of quantities that are related to each other by some rule of correspondence. Here are some examples.

1. The simple interest $I$ earned on \$1000 for 1 year is related to the annual interest rate $r$ by the formula $I = 1000r$.
2. The distance $d$ traveled on a bicycle in 2 hours is related to the speed $s$ of the bicycle by the formula $d = 2s$.
3. The area $A$ of a circle is related to its radius $r$ by the formula $A = \pi r^2$.

Not all correspondences between two quantities have simple mathematical formulas. For instance, people commonly match up NFL starting quarterbacks with touchdown passes, and hours of the day with temperature. In each of these cases, however, there is some rule of correspondence that matches each item from one set with exactly one item from a different set. Such a rule of correspondence is called a **function.**

**Definition of a Function**

A **function** $f$ from a set $A$ to a set $B$ is a rule of correspondence that assigns to each element $x$ in the set $A$ exactly one element $y$ in the set $B$. The set $A$ is the **domain** (or set of inputs) of the function $f$, and the set $B$ contains the **range** (or set of outputs).

**Figure 1.1**



To help understand this definition, look at the function illustrated in Figure 1.1. This function can be represented by the following ordered pairs.

$\{(1, 9°), (2, 13°), (3, 15°), (4, 15°), (5, 12°), (6, 10°)\}$

In each ordered pair, the first coordinate is the input and the second coordinate is the output. In this example, note the following characteristics of a function.

1. Each element in $A$ must be matched with an element of $B$.
2. Some elements in $B$ may not be matched with any element in $A$.
3. Two or more elements of $A$ may be matched with the same element of $B$.

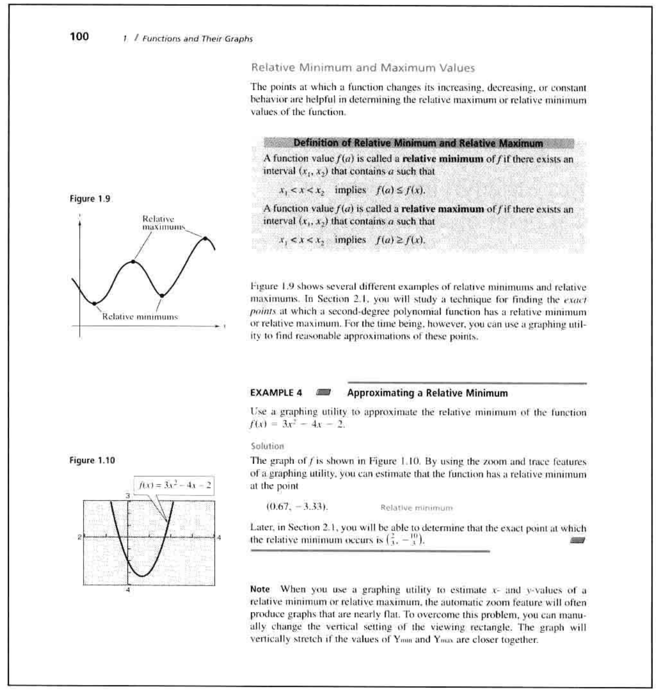
The converse of the third statement is not true. That is, an element of $A$ (the domain) cannot be matched with two different elements of $B$.

**Section Outline** Each section begins with a list of the major topics covered in the section. These topics are also the subsection titles and can be used for easy reference and review by students. In addition, an exercise application that uses a skill or illustrates a concept covered in the section is highlighted to emphasize the connection between mathematical concepts and real-life situations.

**Library of Functions** The concept of the function is introduced in Chapter 1. In the material that follows, the icon  appears each time a new type of function is described in detail.

**Intuitive Foundation for Calculus** Special emphasis is given to the algebraic skills that are needed in calculus. Many examples in the Second Edition discuss algebraic techniques or graphically show concepts that are used in calculus, providing an intuitive foundation for future work.

**Notes** Notes anticipate students' needs by offering additional insights, pointing out common errors, and describing generalizations.



100 1 / Functions and Their Graphs

Relative Minimum and Maximum Values

The points at which a function changes its increasing, decreasing, or constant behavior are helpful in determining the relative maximum or relative minimum values of the function.

**Definition of Relative Minimum and Relative Maximum**

A function value $f(a)$ is called a **relative minimum** of $f$ if there exists an interval $(x_1, x_2)$ that contains $a$ such that

$$x_1 < x < x_2 \quad \text{implies} \quad f(a) \le f(x).$$

A function value $f(a)$ is called a **relative maximum** of $f$ if there exists an interval $(x_1, x_2)$ that contains $a$ such that

$$x_1 < x < x_2 \quad \text{implies} \quad f(a) \ge f(x).$$

Figure 1.9



Figure 1.9 shows several different examples of relative minimums and relative maximums. In Section 2.1, you will study a technique for finding the *exact points* at which a second-degree polynomial function has a relative minimum or relative maximum. For the time being, however, you can use a graphing utility to find reasonable approximations of these points.

**EXAMPLE 4 Approximating a Relative Minimum**

Use a graphing utility to approximate the relative minimum of the function $f(x) = 3x^2 - 4x - 2$.

Solution

The graph of $f$ is shown in Figure 1.10. By using the zoom and trace features of a graphing utility, you can estimate that the function has a relative minimum at the point

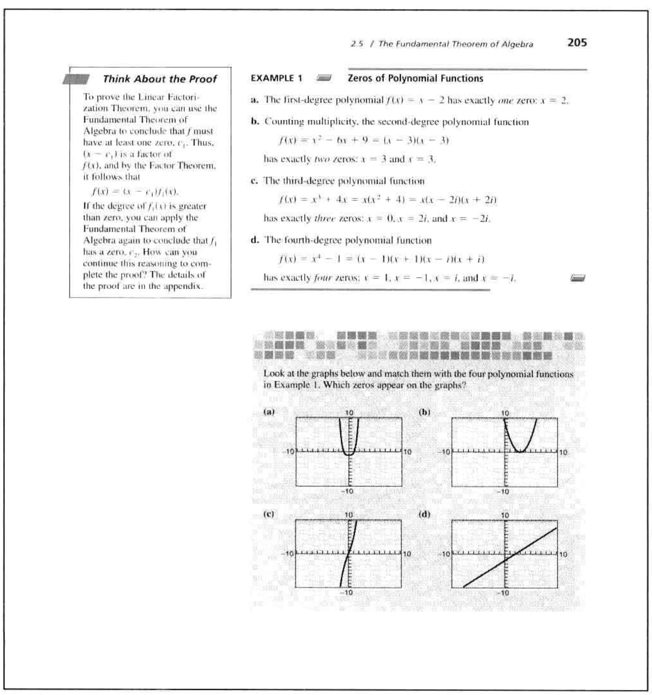
$(0.67, -3.33)$. Relative minimum

Later, in Section 2.1, you will be able to determine that the exact point at which the relative minimum occurs is $(\frac{2}{3}, -\frac{10}{3})$.

Figure 1.10



**Note** When you use a graphing utility to estimate $x$- and $y$-values of a relative minimum or relative maximum, the automatic zoom feature will often produce graphs that are nearly flat. To overcome this problem, you can manually change the vertical setting of the viewing rectangle. The graph will vertically stretch if the values of $Y_{min}$ and $Y_{max}$ are closer together.



2.5 / The Fundamental Theorem of Algebra 205

***Think About the Proof***

To prove the Linear Factorization Theorem, you can use the Fundamental Theorem of Algebra to conclude that $f$ must have at least one zero, $c_1$. Thus, $(x - c_1)$ is a factor of $f(x)$, and by the Factor Theorem, it follows that

$f(x) = (x - c_1)f_1(x)$.

If the degree of $f_1(x)$ is greater than zero, you can apply the Fundamental Theorem of Algebra again to conclude that $f_1$ has a zero, $c_2$. How can you continue this reasoning to complete the proof? The details of the proof are in the appendix.

**EXAMPLE 1 Zeros of Polynomial Functions**

**a.** The first-degree polynomial $f(x) = x - 2$ has exactly *one* zero: $x = 2$.

**b.** Counting multiplicity, the second-degree polynomial function

$$f(x) = x^2 - 6x + 9 = (x - 3)(x - 3)$$

has exactly *two* zeros: $x = 3$ and $x = 3$.

**c.** The third-degree polynomial function

$$f(x) = x^3 + 4x = x(x^2 + 4) = x(x - 2i)(x + 2i)$$

has exactly *three* zeros: $x = 0$, $x = 2i$, and $x = -2i$.

**d.** The fourth-degree polynomial function

$$f(x) = x^4 - 1 = (x - 1)(x + 1)(x - i)(x + i)$$

has exactly *four* zeros: $x = 1$, $x = -1$, $x = i$, and $x = -i$.

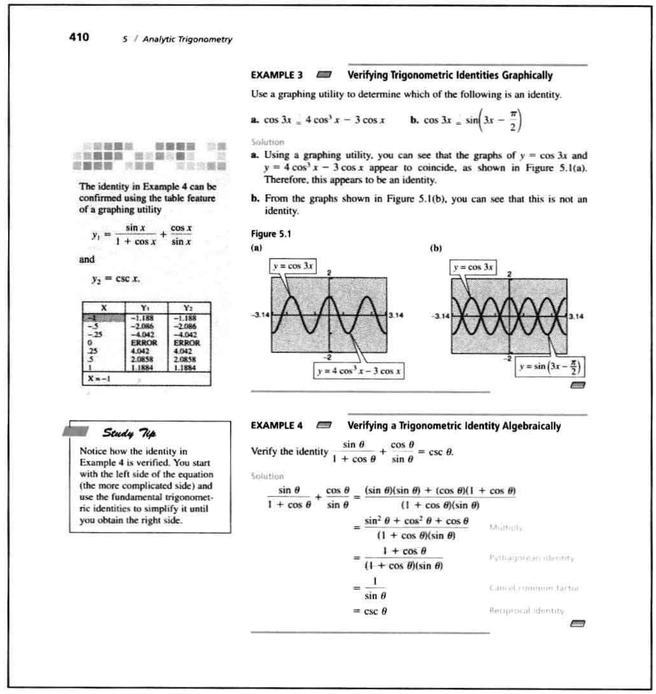
Look at the graphs below and match them with the four polynomial functions in Example 1. Which zeros appear on the graphs?



**Think About the Proof** Located in the margin adjacent to the corresponding theorem, each Think About the Proof feature offers strategies for proving the theorem. Detailed proofs for all theorems are given in Appendix A.

**Technology** Technology is integrated throughout the text at point of use as a tool for visualization, investigation, and verification. Instructions for using graphing utilities are given as necessary.

**Study Tips** Study Tips appear in the margin at point of use and offer students specific suggestions for studying algebra.



410 *5 / Analytic Trigonometry*

The identity in Example 4 can be confirmed using the table feature of a graphing utility

$$y_1 = \frac{\sin x}{1 + \cos x} + \frac{\cos x}{\sin x}$$

and

$$y_2 = \csc x.$$

| X | $Y_1$ | $Y_2$ |
|---|---|---|
| −1 | −1.188 | −1.188 |
| −.5 | −2.086 | −2.086 |
| −.25 | −4.042 | −4.042 |
| 0 | ERROR | ERROR |
| .25 | 4.042 | 4.042 |
| .5 | 2.0858 | 2.0858 |
| 1 | 1.1884 | 1.1884 |
| X = −1 | | |

**Study Tip**

Notice how the identity in Example 4 is verified. You start with the left side of the equation (the more complicated side) and use the fundamental trigonometric identities to simplify it until you obtain the right side.

**EXAMPLE 3 Verifying Trigonometric Identities Graphically**

Use a graphing utility to determine which of the following is an identity.

**a.** $\cos 3x \stackrel{?}{=} 4\cos^3 x - 3\cos x$ **b.** $\cos 3x \stackrel{?}{=} \sin\left(3x - \frac{\pi}{2}\right)$

Solution

**a.** Using a graphing utility, you can see that the graphs of $y = \cos 3x$ and $y = 4\cos^3 x - 3\cos x$ appear to coincide, as shown in Figure 5.1(a). Therefore, this appears to be an identity.

**b.** From the graphs shown in Figure 5.1(b), you can see that this is not an identity.

Figure 5.1



**EXAMPLE 4 Verifying a Trigonometric Identity Algebraically**

Verify the identity $\frac{\sin\theta}{1 + \cos\theta} + \frac{\cos\theta}{\sin\theta} = \csc\theta$.

Solution

$$\frac{\sin\theta}{1 + \cos\theta} + \frac{\cos\theta}{\sin\theta} = \frac{(\sin\theta)(\sin\theta) + (\cos\theta)(1 + \cos\theta)}{(1 + \cos\theta)(\sin\theta)}$$

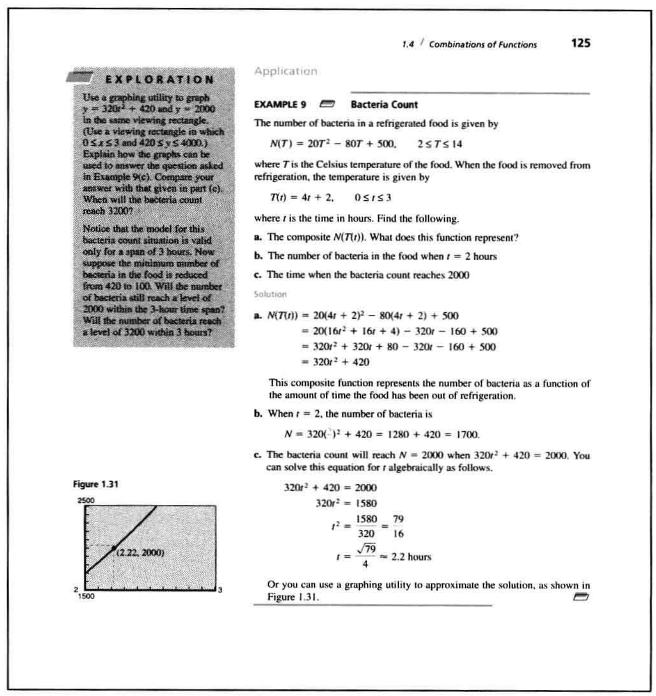
$$= \frac{\sin^2\theta + \cos^2\theta + \cos\theta}{(1 + \cos\theta)(\sin\theta)} \quad \text{Multiply}$$

$$= \frac{1 + \cos\theta}{(1 + \cos\theta)(\sin\theta)} \quad \text{Pythagorean identity}$$

$$= \frac{1}{\sin\theta} \quad \text{Cancel common factor}$$

$$= \csc\theta \quad \text{Reciprocal identity}$$

**Exploration** Throughout the text, the Exploration features encourage active participation by students, strengthening their intuition and critical thinking skills by exploring mathematical concepts and discovering mathematical relationships. Using a variety of approaches—including visualization, verification, use of graphing utilities, pattern recognition, and modeling—students are encouraged to develop a conceptual understanding of theoretical topics.



*1.4 / Combinations of Functions* 125

**EXPLORATION**

Use a graphing utility to graph $y = 320t^2 + 420$ and $y = 2000$ in the same viewing rectangle. (Use a viewing rectangle in which $0 \le x \le 3$ and $420 \le y \le 4000$.) Explain how the graphs can be used to answer the question asked in Example 9(c). Compare your answer with that given in part (c). When will the bacteria count reach 3200?

Notice that the model for this bacteria count situation is valid only for a span of 3 hours. Now suppose the minimum number of bacteria in the food is reduced from 420 to 100. Will the number of bacteria still reach a level of 2000 within the 3-hour time span? Will the number of bacteria reach a level of 3200 within 3 hours?

Application

**EXAMPLE 9 Bacteria Count**

The number of bacteria in a refrigerated food is given by

$$N(T) = 20T^2 - 80T + 500, \quad 2 \le T \le 14$$

where $T$ is the Celsius temperature of the food. When the food is removed from refrigeration, the temperature is given by

$$T(t) = 4t + 2, \quad 0 \le t \le 3$$

where $t$ is the time in hours. Find the following.

**a.** The composite $N(T(t))$. What does this function represent?

**b.** The number of bacteria in the food when $t = 2$ hours

**c.** The time when the bacteria count reaches 2000

Solution

**a.** $N(T(t)) = 20(4t + 2)^2 - 80(4t + 2) + 500$
$= 20(16t^2 + 16t + 4) - 320t - 160 + 500$
$= 320t^2 + 320t + 80 - 320t - 160 + 500$
$= 320t^2 + 420$

This composite function represents the number of bacteria as a function of the amount of time the food has been out of refrigeration.

**b.** When $t = 2$, the number of bacteria is

$$N = 320(\ )^2 + 420 = 1280 + 420 = 1700.$$

**c.** The bacteria count will reach $N = 2000$ when $320t^2 + 420 = 2000$. You can solve this equation for $t$ algebraically as follows.

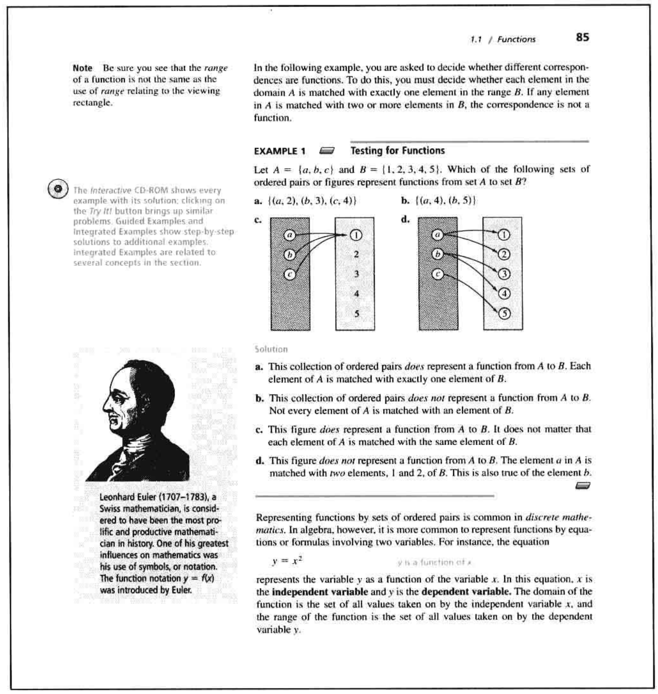
$$320t^2 + 420 = 2000$$
$$320t^2 = 1580$$
$$t^2 = \frac{1580}{320} = \frac{79}{16}$$
$$t = \frac{\sqrt{79}}{4} \approx 2.2 \text{ hours}$$

Or you can use a graphing utility to approximate the solution, as shown in Figure 1.31.

Figure 1.31

**Historical Notes** To help students understand that algebra has a past, historical notes featuring mathematicians and their work and mathematical artifacts are included in each chapter.

**Graphics** Visualization is a critical problem-solving skill. To encourage the development of this ability, the text has nearly 2300 figures in examples, exercises, and answers to exercises. Included are graphs of equations and functions, geometric figures, displays of statistical information, scatter plots, and numerous screen outputs from graphing technology. All graphs of equations and functions are computer- or calculator-generated for accuracy, and they are designed to resemble students' actual screen outputs as closely as possible. Graphics are also used to emphasize graphical interpretation, comparison, and estimation.



1.1 / Functions 85

**Note** Be sure you see that the *range* of a function is not the same as the use of *range* relating to the viewing rectangle.

In the following example, you are asked to decide whether different correspondences are functions. To do this, you must decide whether each element in the domain $A$ is matched with exactly one element in the range $B$. If any element in $A$ is matched with two or more elements in $B$, the correspondence is not a function.

The *Interactive* CD-ROM shows every example with its solution; clicking on the *Try It!* button brings up similar problems. Guided Examples and Integrated Examples show step-by-step solutions to additional examples. Integrated Examples are related to several concepts in the section.

**EXAMPLE 1** **Testing for Functions**

Let $A = \{a, b, c\}$ and $B = \{1, 2, 3, 4, 5\}$. Which of the following sets of ordered pairs or figures represent functions from set $A$ to set $B$?

**a.** $\{(a, 2), (b, 3), (c, 4)\}$ **b.** $\{(a, 4), (b, 5)\}$

**c.** **d.**



Solution

**a.** This collection of ordered pairs *does* represent a function from $A$ to $B$. Each element of $A$ is matched with exactly one element of $B$.

**b.** This collection of ordered pairs *does not* represent a function from $A$ to $B$. Not every element of $A$ is matched with an element of $B$.

**c.** This figure *does* represent a function from $A$ to $B$. It does not matter that each element of $A$ is matched with the same element of $B$.

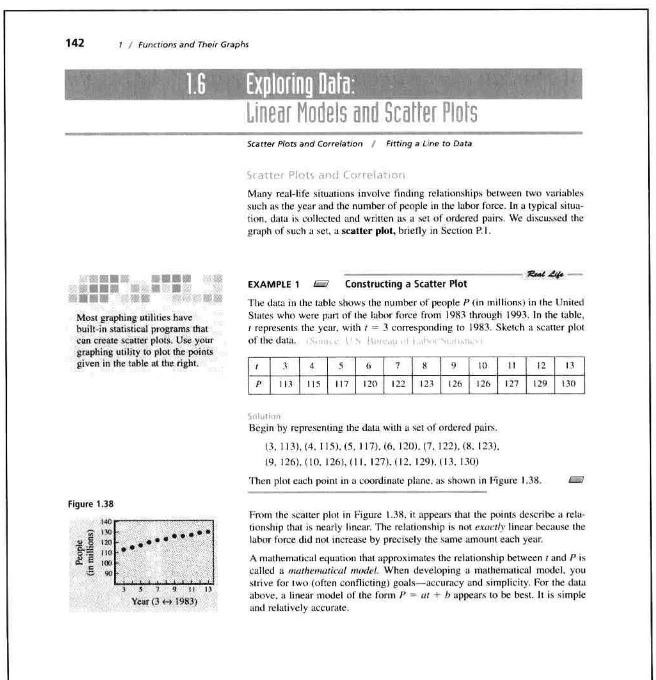
**d.** This figure *does not* represent a function from $A$ to $B$. The element $a$ in $A$ is matched with *two* elements, 1 and 2, of $B$. This is also true of the element $b$.

**Leonhard Euler (1707–1783), a Swiss mathematician, is considered to have been the most prolific and productive mathematician in history. One of his greatest influences on mathematics was his use of symbols, or notation. The function notation $y = f(x)$ was introduced by Euler.**

Representing functions by sets of ordered pairs is common in *discrete mathematics*. In algebra, however, it is more common to represent functions by equations or formulas involving two variables. For instance, the equation

$$y = x^2 \qquad y \text{ is a function of } x$$

represents the variable $y$ as a function of the variable $x$. In this equation, $x$ is the **independent variable** and $y$ is the **dependent variable.** The domain of the function is the set of all values taken on by the independent variable $x$, and the range of the function is the set of all values taken on by the dependent variable $y$.



142 1 / Functions and Their Graphs

1.6 Exploring Data: Linear Models and Scatter Plots

*Scatter Plots and Correlation / Fitting a Line to Data*

Scatter Plots and Correlation

Many real-life situations involve finding relationships between two variables such as the year and the number of people in the labor force. In a typical situation, data is collected and written as a set of ordered pairs. We discussed the graph of such a set, a **scatter plot,** briefly in Section P.1.

Most graphing utilities have built-in statistical programs that can create scatter plots. Use your graphing utility to plot the points given in the table at the right.

**EXAMPLE 1** **Constructing a Scatter Plot** *Real Life*

The data in the table shows the number of people $P$ (in millions) in the United States who were part of the labor force from 1983 through 1993. In the table, $t$ represents the year, with $t = 3$ corresponding to 1983. Sketch a scatter plot of the data. (Source: U.S. Bureau of Labor Statistics)

| $t$ | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $P$ | 113 | 115 | 117 | 120 | 122 | 123 | 126 | 126 | 127 | 129 | 130 |

Solution

Begin by representing the data with a set of ordered pairs.

(3, 113), (4, 115), (5, 117), (6, 120), (7, 122), (8, 123),
(9, 126), (10, 126), (11, 127), (12, 129), (13, 130)

Then plot each point in a coordinate plane, as shown in Figure 1.38.

Figure 1.38



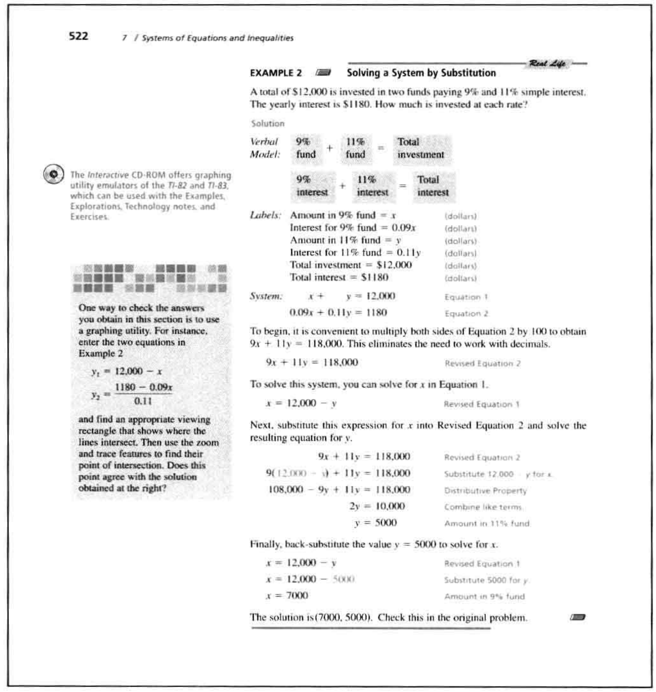
From the scatter plot in Figure 1.38, it appears that the points describe a relationship that is nearly linear. The relationship is not *exactly* linear because the labor force did not increase by precisely the same amount each year.

A mathematical equation that approximates the relationship between $t$ and $P$ is called a *mathematical model.* When developing a mathematical model, you strive for two (often conflicting) goals—accuracy and simplicity. For the data above, a linear model of the form $P = at + b$ appears to be best. It is simple and relatively accurate.

**Applications** Real-life applications are integrated throughout the text in examples and exercises. These applications offer students constant review of problem-solving skills, and they emphasize the relevance of the mathematics. Many of the applications use recent, real data, and all are titled for easy reference. Photographs with captions in the introduction to the chapter also encourage students to see the link between mathematics and real life.

**Examples** Each of the more than 500 text examples was carefully chosen to illustrate a particular mathematical concept, problem-solving approach, or computational technique, and to enhance students' understanding. The examples in the text cover a wide variety of problem types, including theoretical problems, real-life applications (many with real data), and problems requiring the use of graphing technology. Each example is titled for easy reference, and real-life applications are labeled. Many examples include side comments in color that clarify the steps of the solution.

**Problem Solving** The text provides ample opportunity for students to hone their problem-solving skills. In both the exercises and the examples in the Second Edition, students are asked to apply verbal, analytical, graphical, and numerical approaches to problem solving. Students are also encouraged to use a graphing utility as a tool for solving problems. Students are taught the following approach to solving applied problems: (1) construct a verbal model; (2) label variable and constant terms; (3) construct an algebraic model; (4) using the model, solve the problem; and (5) check the answer in the original statement of the problem.



522 7 / Systems of Equations and Inequalities

Real Life

**EXAMPLE 2 Solving a System by Substitution**

A total of $12,000 is invested in two funds paying 9% and 11% simple interest. The yearly interest is $1180. How much is invested at each rate?

Solution

*Verbal Model:* 9% fund + 11% fund = Total investment

9% interest + 11% interest = Total interest

*Labels:* Amount in 9% fund $= x$ (dollars)
Interest for 9% fund $= 0.09x$ (dollars)
Amount in 11% fund $= y$ (dollars)
Interest for 11% fund $= 0.11y$ (dollars)
Total investment $= \$12{,}000$ (dollars)
Total interest $= \$1180$ (dollars)

*System:* $x + y = 12{,}000$ Equation 1
$0.09x + 0.11y = 1180$ Equation 2

To begin, it is convenient to multiply both sides of Equation 2 by 100 to obtain $9x + 11y = 118{,}000$. This eliminates the need to work with decimals.

$9x + 11y = 118{,}000$ Revised Equation 2

To solve this system, you can solve for $x$ in Equation 1.

$x = 12{,}000 - y$ Revised Equation 1

Next, substitute this expression for $x$ into Revised Equation 2 and solve the resulting equation for $y$.

$9x + 11y = 118{,}000$ Revised Equation 2
$9(12{,}000 - y) + 11y = 118{,}000$ Substitute $12{,}000 - y$ for $x$.
$108{,}000 - 9y + 11y = 118{,}000$ Distributive Property
$2y = 10{,}000$ Combine like terms.
$y = 5000$ Amount in 11% fund

Finally, back-substitute the value $y = 5000$ to solve for $x$.

$x = 12{,}000 - y$ Revised Equation 1
$x = 12{,}000 - 5000$ Substitute 5000 for $y$.
$x = 7000$ Amount in 9% fund

The solution is (7000, 5000). Check this in the original problem.

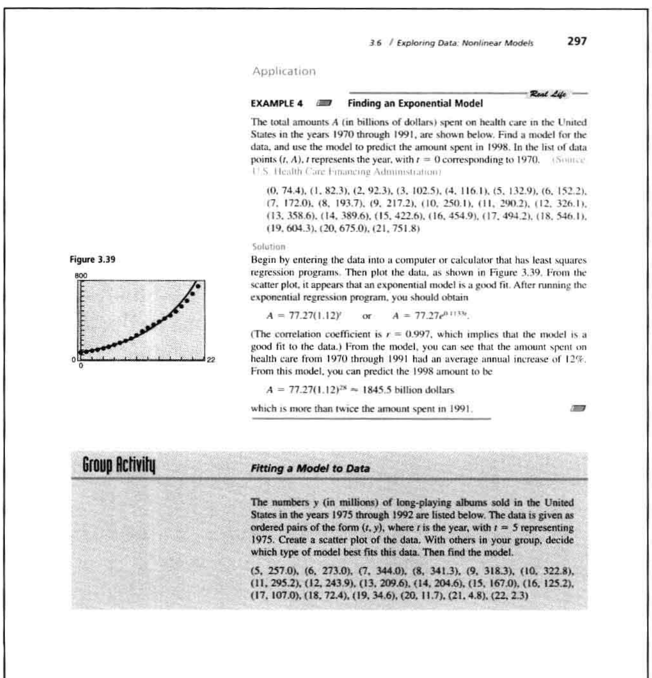
The *Interactive* CD-ROM offers graphing utility emulators of the *TI-82* and *TI-83*, which can be used with the Examples, Explorations, Technology notes, and Exercises.

One way to check the answers you obtain in this section is to use a graphing utility. For instance, enter the two equations in Example 2

$y_1 = 12{,}000 - x$

$y_2 = \dfrac{1180 - 0.09x}{0.11}$

and find an appropriate viewing rectangle that shows where the lines intersect. Then use the zoom and trace features to find their point of intersection. Does this point agree with the solution obtained at the right?



3.6 / Exploring Data: Nonlinear Models 297

Application

Real Life

**EXAMPLE 4 Finding an Exponential Model**

The total amounts $A$ (in billions of dollars) spent on health care in the United States in the years 1970 through 1991, are shown below. Find a model for the data, and use the model to predict the amount spent in 1998. In the list of data points $(t, A)$, $t$ represents the year, with $t = 0$ corresponding to 1970. (Source: U.S. Health Care Financing Administration)

(0, 74.4), (1, 82.3), (2, 92.3), (3, 102.5), (4, 116.1), (5, 132.9), (6, 152.2), (7, 172.0), (8, 193.7), (9, 217.2), (10, 250.1), (11, 290.2), (12, 326.1), (13, 358.6), (14, 389.6), (15, 422.6), (16, 454.9), (17, 494.2), (18, 546.1), (19, 604.3), (20, 675.0), (21, 751.8)

Solution

Begin by entering the data into a computer or calculator that has least squares regression programs. Then plot the data, as shown in Figure 3.39. From the scatter plot, it appears that an exponential model is a good fit. After running the exponential regression program, you should obtain

$A = 77.27(1.12)^t$ or $A = 77.27e^{0.1133t}$.

(The correlation coefficient is $r = 0.997$, which implies that the model is a good fit to the data.) From the model, you can see that the amount spent on health care from 1970 through 1991 had an average annual increase of 12%. From this model, you can predict the 1998 amount to be

$A = 77.27(1.12)^{28} \approx 1845.5$ billion dollars

which is more than twice the amount spent in 1991.

Figure 3.39



**Group Activity** *Fitting a Model to Data*

The numbers $y$ (in millions) of long-playing albums sold in the United States in the years 1975 through 1992 are listed below. The data is given as ordered pairs of the form $(t, y)$, where $t$ is the year, with $t = 5$ representing 1975. Create a scatter plot of the data. With others in your group, decide which type of model best fits this data. Then find the model.

(5, 257.0), (6, 273.0), (7, 344.0), (8, 341.3), (9, 318.3), (10, 322.8), (11, 295.2), (12, 243.9), (13, 209.6), (14, 204.6), (15, 167.0), (16, 125.2), (17, 107.0), (18, 72.4), (19, 34.6), (20, 11.7), (21, 4.8), (22, 2.3)

**CD-ROM** The icon refers to additional features of *Precalculus Functions and Graphs: A Graphing Approach; A Self-Guided Study Companion* that enhance the text presentation, such as exercises, computer animations, examples, tests, and *TI-82* and *TI-83* graphing calculator emulators.

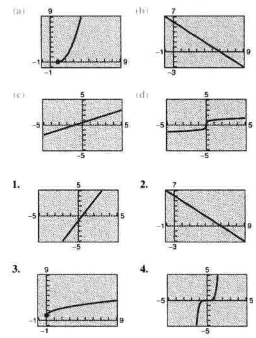
**Group Activities** The Group Activities that appear at the ends of sections reinforce students' understanding by studying mathematical concepts in a variety of ways, including talking and writing about mathematics, creating and solving problems, analyzing errors, and developing and using mathematical models. Designed to be completed as group projects in class or as homework assignments, the Group Activities give students opportunities to do interactive learning and to think, talk, and write about mathematics.

**Exercises** The exercise sets were completely revised for the Second Edition. More than 5200 exercises with a broad range of conceptual, computational, and applied problems accommodate a variety of teaching and learning styles. Included in the section and review exercise sets are multipart, writing, and more challenging problems with extensive graphics that encourage exploration and discovery, enhance students' skills in mathematical modeling, estimation, and data interpretation and analysis, and encourage the use of graphing technology for conceptual understanding. Applications are labeled for easy reference. The exercise sets are designed to build competence, skill, and understanding; each exercise set is graded in difficulty to allow students to gain confidence as they progress. Detailed solutions to all odd-numbered exercises are given in the *Study and Solutions Guide;* answers to all odd-numbered exercises appear in the back of the text.

1.5 / *Inverse Functions* 139

## 1.5 /// EXERCISES

In Exercises 1–4, match the graph of the function with the graph of its inverse. [The graphs of the inverse functions are labeled (a), (b), (c), and (d).]




In Exercises 5–10, find the inverse of $f$ informally. Verify that $f(f^{-1}(x)) = x$ and $f^{-1}(f(x)) = x$.

**5.** $f(x) = 8x$ **6.** $f(x) = \frac{1}{5}x$

**7.** $f(x) = x + 10$ **8.** $f(x) = x - 5$

**9.** $f(x) = \sqrt[3]{x}$ **10.** $f(x) = x^5$

In Exercises 11–14, show that $f$ and $g$ are inverse functions (a) algebraically and (b) graphically.

**11.** $f(x) = 2x,\ g(x) = \frac{x}{2}$

**12.** $f(x) = x - 5,\ g(x) = x + 5$

**13.** $f(x) = 5x + 1,\ g(x) = \frac{x-1}{5}$

**14.** $f(x) = 3 - 4x,\ g(x) = \frac{3-x}{4}$

In Exercises 15–20, show that $f$ and $g$ are inverse functions algebraically. Use a graphing utility to graph $f$ and $g$ in the same viewing rectangle. Describe the relationship between the graphs.

**15.** $f(x) = x^3,\ g(x) = \sqrt[3]{x}$

**16.** $f(x) = \frac{1}{x},\ g(x) = \frac{1}{x}$

**17.** $f(x) = \sqrt{x-4},\ g(x) = x^2 + 4,\ x \geq 0$

**18.** $f(x) = 9 - x^2,\ x \geq 0$
$g(x) = \sqrt{9-x},\ x \leq 9$

**19.** $f(x) = 1 - x^3,\ g(x) = \sqrt[3]{1-x}$

**20.** $f(x) = \frac{1}{1+x},\ x \geq 0$
$g(x) = \frac{1-x}{x},\ 0 < x \leq 1$

In Exercises 21–30, use a graphing utility to graph the function and use the Horizontal Line Test to determine whether the function is one-to-one.

**21.** $f(x) = 3 - \frac{1}{2}x$ **22.** $h(x) = \sqrt{16 - x^2}$

**23.** $h(x) = \frac{x^2}{x^2+1}$ **24.** $f(x) = \sqrt{x-2}$

**25.** $g(x) = \frac{4-x}{6}$ **26.** $f(x) = 10$

7.1 / *Solving Systems of Equations* 529

**62.** *Investment Portfolio* A total of \$25,000 is invested in two funds paying 6% and 8.5% simple interest. The 6% investment has a lower risk. The investor wants a yearly interest income of \$2000 from the two investments.

(a) Write a system of equations in which one equation represents the total amount invested and the other equation represents the \$2000 required in interest. Let $x$ and $y$ represent the amounts invested at 6% and 8.5%, respectively.

(b) Use a graphing utility to graph the two equations. As the amount invested at 6% increases, how does the amount invested at 8.5% change and how does the amount of interest change? Explain.

(c) What is the most that can be invested at 6% to meet the requirement of \$2000 per year in interest?

**63.** *Choice of Two Jobs* You are offered two different jobs selling dental supplies.

- One company offers a straight commission of 6% of sales.
- The other company offers a salary of \$250 per week plus 3% of sales.

How much would you have to sell in a week in order to make the straight commission offer better?

**64.** *Choice of Two Jobs* You are offered two different jobs selling college textbooks.

- One company offers an annual salary of \$20,000 plus a year-end bonus of 1% of your total sales.
- The other company offers an annual salary of \$15,000 plus a year-end bonus of 2% of your total sales.

Determine the annual sales that make the second offer better.

**65.** *Market Equilibrium* The supply and demand curves for a business dealing with wheat are given by

Supply: $p = 1.45 + 0.00014x^2$
Demand: $p = (2.388 - 0.007x)^2$

where $p$ is the price in dollars per bushel and $x$ is the quantity in bushels per day. Use a graphing utility to graph the supply and demand equations and find the market equilibrium. (The *market equilibrium* is the point of intersection of the graphs for $x > 0$.)

**66.** *Log Volume* You are offered two different rules for estimating the number of board feet in a log that is 16 feet long. One is the *Doyle Log Rule* and is modeled by

$$V = (D - 4)^2, \quad 5 \leq D \leq 40$$

and the other is the *Scribner Log Rule* and is modeled by

$$V = 0.79D^2 - 2D - 4, \quad 5 \leq D \leq 40$$

where $D$ is the diameter of the log and $V$ is its volume in board feet.

(a) Use a graphing utility to graph the log rules in the same viewing rectangle.

(b) For what diameter do the two rules agree?

(c) If you were selling large logs, which rule would you use? Explain your reasoning.

*Geometry* In Exercises 67–70, find the dimensions of the rectangle meeting the specified conditions.

| | *Perimeter* | *Condition* |
|---|---|---|
| **67.** | 30 meters | The length is 3 meters greater than the width. |
| **68.** | 280 centimeters | The width is 20 centimeters less than the length. |
| **69.** | 42 inches | The width is three-fourths the length. |
| **70.** | 210 feet | The length is one and one-half times the width. |

**71.** *Geometry* What are the dimensions of a rectangular tract of land if its perimeter is 40 miles and its area is 96 square miles?

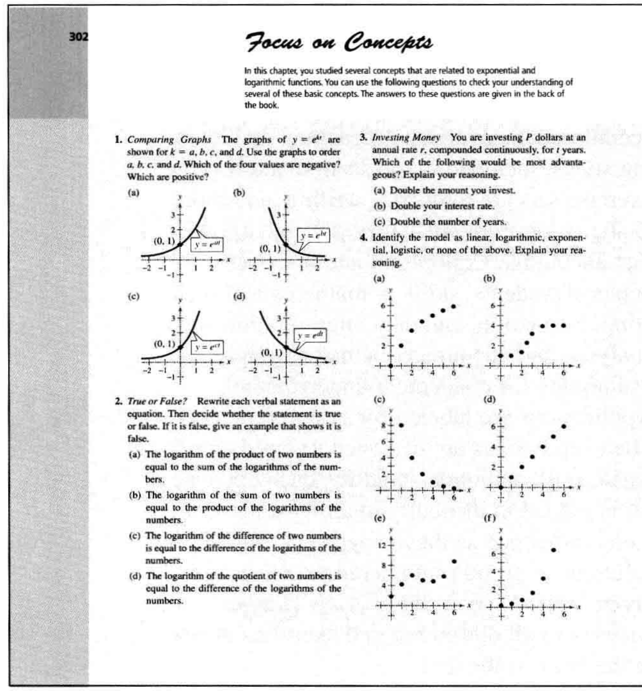
**72.** *Geometry* What are the dimensions of an isosceles right triangle with a 2-inch hypotenuse and an area of 1 square inch?

**73.** *Exploration* Find an equation of a line whose graph intersects the graph of the parabola $y = x^2$ at the following numbers of points. (There is more than one correct answer.)

(a) Two points
(b) One point
(c) No points

**Geometry** Geometric formulas and concepts are reviewed throughout the text in examples, Group Activities, and exercises. For reference, common formulas are listed inside the back cover of this text.

**Focus on Concepts** Each Focus on Concepts feature is a set of exercises that test students' understanding of the basic concepts covered in the chapter. Answers to all questions are given in the back of the text.



302

# Focus on Concepts

In this chapter, you studied several concepts that are related to exponential and logarithmic functions. You can use the following questions to check your understanding of several of these basic concepts. The answers to these questions are given in the back of the book.

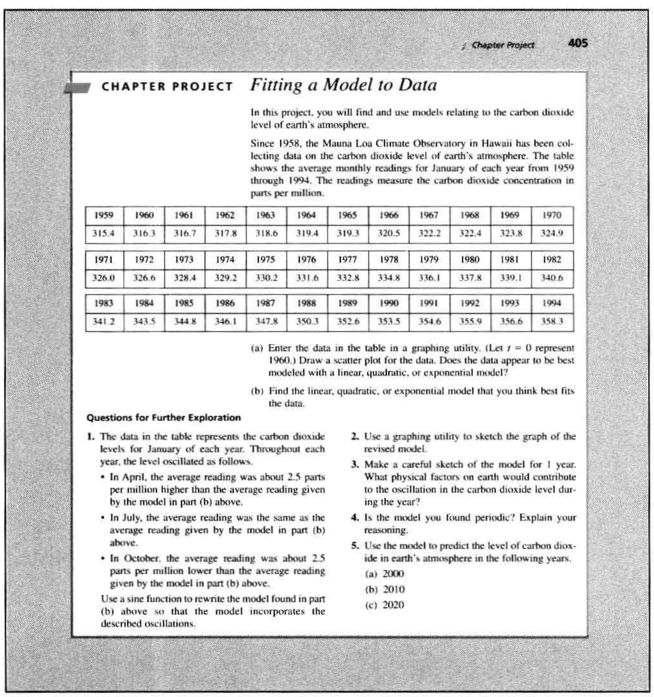
1. *Comparing Graphs* The graphs of $y = e^{kt}$ are shown for $k = a, b, c$, and $d$. Use the graphs to order $a, b, c$, and $d$. Which of the four values are negative? Which are positive?

2. *True or False?* Rewrite each verbal statement as an equation. Then decide whether the statement is true or false. If it is false, give an example that shows it is false.
   (a) The logarithm of the product of two numbers is equal to the sum of the logarithms of the numbers.
   (b) The logarithm of the sum of two numbers is equal to the product of the logarithms of the numbers.
   (c) The logarithm of the difference of two numbers is equal to the difference of the logarithms of the numbers.
   (d) The logarithm of the quotient of two numbers is equal to the difference of the logarithms of the numbers.

3. *Investing Money* You are investing $P$ dollars at an annual rate $r$, compounded continuously, for $t$ years. Which of the following would be most advantageous? Explain your reasoning.
   (a) Double the amount you invest.
   (b) Double your interest rate.
   (c) Double the number of years.

4. Identify the model as linear, logarithmic, exponential, logistic, or none of the above. Explain your reasoning.

**Chapter Projects** Chapter Projects are extended applications that use real data, graphs, and modeling to enhance students' understanding of mathematical concepts. Designed as individual or group projects, they offer additional opportunities to think, discuss, and write about mathematics. Many projects give students the opportunity to collect, analyze, and interpret data.



Chapter Project 405

CHAPTER PROJECT *Fitting a Model to Data*

In this project, you will find and use models relating to the carbon dioxide level of earth's atmosphere.

Since 1958, the Mauna Loa Climate Observatory in Hawaii has been collecting data on the carbon dioxide level of earth's atmosphere. The table shows the average monthly readings for January of each year from 1959 through 1994. The readings measure the carbon dioxide concentration in parts per million.

| 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 315.4 | 316.3 | 316.7 | 317.8 | 318.6 | 319.4 | 319.3 | 320.5 | 322.2 | 322.4 | 323.8 | 324.9 |

| 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 326.0 | 326.6 | 328.4 | 329.2 | 330.2 | 331.6 | 332.8 | 334.8 | 336.1 | 337.8 | 339.1 | 340.6 |

| 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 341.2 | 343.5 | 344.8 | 346.1 | 347.8 | 350.3 | 352.6 | 353.5 | 354.6 | 355.9 | 356.6 | 358.3 |

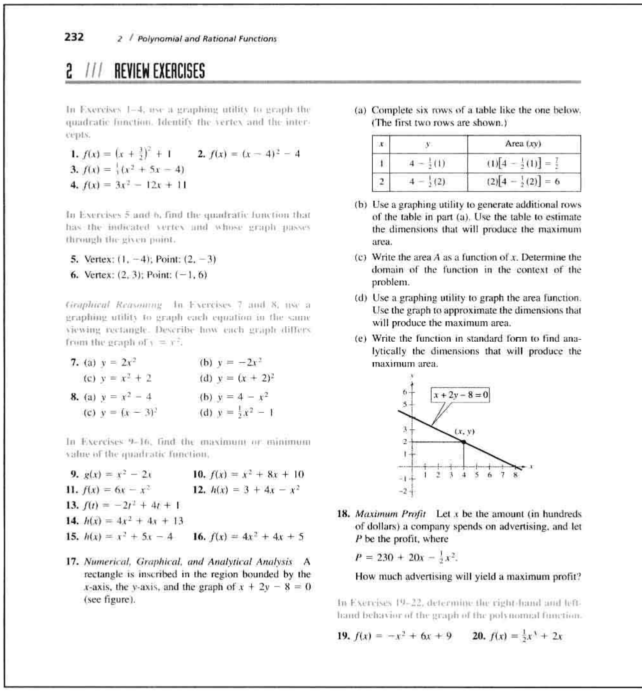
(a) Enter the data in the table in a graphing utility. (Let $t = 0$ represent 1960.) Draw a scatter plot for the data. Does the data appear to be best modeled with a linear, quadratic, or exponential model?

(b) Find the linear, quadratic, or exponential model that you think best fits the data.

**Questions for Further Exploration**

1. The data in the table represents the carbon dioxide levels for January of each year. Throughout each year, the level oscillated as follows.
   - In April, the average reading was about 2.5 parts per million higher than the average reading given by the model in part (b) above.
   - In July, the average reading was the same as the average reading given by the model in part (b) above.
   - In October, the average reading was about 2.5 parts per million lower than the average reading given by the model in part (b) above.

   Use a sine function to rewrite the model found in part (b) above so that the model incorporates the described oscillations.
2. Use a graphing utility to sketch the graph of the revised model.
3. Make a careful sketch of the model for 1 year. What physical factors on earth would contribute to the oscillation in the carbon dioxide level during the year?
4. Is the model you found periodic? Explain your reasoning.
5. Use the model to predict the level of carbon dioxide in earth's atmosphere in the following years.
   (a) 2000
   (b) 2010
   (c) 2020


232 2 / Polynomial and Rational Functions

2 /// REVIEW EXERCISES

In Exercises 1–4, use a graphing utility to graph the quadratic function. Identify the vertex and the intercepts.

1. $f(x) = \left(x + \frac{3}{2}\right)^2 + 1$ 2. $f(x) = (x - 4)^2 - 4$
3. $f(x) = \frac{1}{3}(x^2 + 5x - 4)$
4. $f(x) = 3x^2 - 12x + 11$

In Exercises 5 and 6, find the quadratic function that has the indicated vertex and whose graph passes through the given point.

5. Vertex: (1, −4); Point: (2, −3)
6. Vertex: (2, 3); Point: (−1, 6)

*Graphical Reasoning* In Exercises 7 and 8, use a graphing utility to graph each equation in the same viewing rectangle. Describe how each graph differs from the graph of $y = x^2$.

7. (a) $y = 2x^2$ (b) $y = -2x^2$
(c) $y = x^2 + 2$ (d) $y = (x + 2)^2$
8. (a) $y = x^2 - 4$ (b) $y = 4 - x^2$
(c) $y = (x - 3)^2$ (d) $y = \frac{1}{2}x^2 - 1$

In Exercises 9–16, find the maximum or minimum value of the quadratic function.

9. $g(x) = x^2 - 2x$ 10. $f(x) = x^2 + 8x + 10$
11. $f(x) = 6x - x^2$ 12. $h(x) = 3 + 4x - x^2$
13. $f(t) = -2t^2 + 4t + 1$
14. $h(x) = 4x^2 + 4x + 13$
15. $h(x) = x^2 + 5x - 4$ 16. $f(x) = 4x^2 + 4x + 5$

17. *Numerical, Graphical, and Analytical Analysis* A rectangle is inscribed in the region bounded by the $x$-axis, the $y$-axis, and the graph of $x + 2y - 8 = 0$ (see figure).

(a) Complete six rows of a table like the one below. (The first two rows are shown.)

| $x$ | $y$ | Area $(xy)$ |
|---|---|---|
| 1 | $4 - \frac{1}{2}(1)$ | $(1)\left[4 - \frac{1}{2}(1)\right] = \frac{7}{2}$ |
| 2 | $4 - \frac{1}{2}(2)$ | $(2)\left[4 - \frac{1}{2}(2)\right] = 6$ |

(b) Use a graphing utility to generate additional rows of the table in part (a). Use the table to estimate the dimensions that will produce the maximum area.
(c) Write the area $A$ as a function of $x$. Determine the domain of the function in the context of the problem.
(d) Use a graphing utility to graph the area function. Use the graph to approximate the dimensions that will produce the maximum area.
(e) Write the function in standard form to find analytically the dimensions that will produce the maximum area.



18. *Maximum Profit* Let $x$ be the amount (in hundreds of dollars) a company spends on advertising, and let $P$ be the profit, where

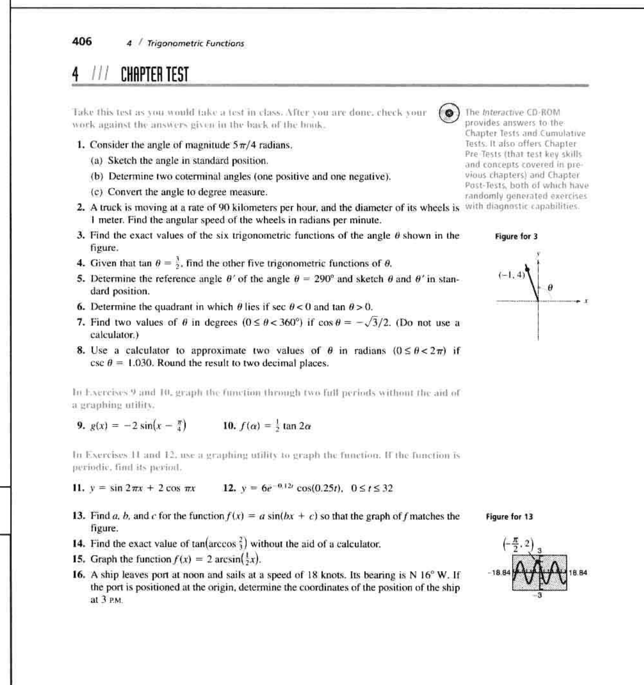
$P = 230 + 20x - \frac{1}{2}x^2$.

How much advertising will yield a maximum profit?

In Exercises 19–22, determine the right-hand and left-hand behavior of the graph of the polynomial function.

19. $f(x) = -x^2 + 6x + 9$ 20. $f(x) = \frac{1}{2}x^3 + 2x$

**Review Exercises** The Review Exercises at the end of each chapter offer students an opportunity for additional practice. Answers to odd-numbered review exercises are given in the back of the text.


406 4 / Trigonometric Functions

4 /// CHAPTER TEST

Take this test as you would take a test in class. After you are done, check your work against the answers given in the back of the book.

The *Interactive* CD-ROM provides answers to the Chapter Tests and Cumulative Tests. It also offers Chapter Pre-Tests (that test key skills and concepts covered in previous chapters) and Chapter Post-Tests, both of which have randomly generated exercises with diagnostic capabilities.

1. Consider the angle of magnitude $5\pi/4$ radians.
(a) Sketch the angle in standard position.
(b) Determine two coterminal angles (one positive and one negative).
(c) Convert the angle to degree measure.
2. A truck is moving at a rate of 90 kilometers per hour, and the diameter of its wheels is 1 meter. Find the angular speed of the wheels in radians per minute.
3. Find the exact values of the six trigonometric functions of the angle $\theta$ shown in the figure.
4. Given that $\tan\theta = \frac{3}{2}$, find the other five trigonometric functions of $\theta$.
5. Determine the reference angle $\theta'$ of the angle $\theta = 290°$ and sketch $\theta$ and $\theta'$ in standard position.
6. Determine the quadrant in which $\theta$ lies if $\sec\theta < 0$ and $\tan\theta > 0$.
7. Find two values of $\theta$ in degrees $(0 \le \theta < 360°)$ if $\cos\theta = -\sqrt{3}/2$. (Do not use a calculator.)
8. Use a calculator to approximate two values of $\theta$ in radians $(0 \le \theta < 2\pi)$ if $\csc\theta = 1.030$. Round the result to two decimal places.

Figure for 3



In Exercises 9 and 10, graph the function through two full periods without the aid of a graphing utility.

9. $g(x) = -2\sin\left(x - \frac{\pi}{4}\right)$ 10. $f(\alpha) = \frac{1}{2}\tan 2\alpha$

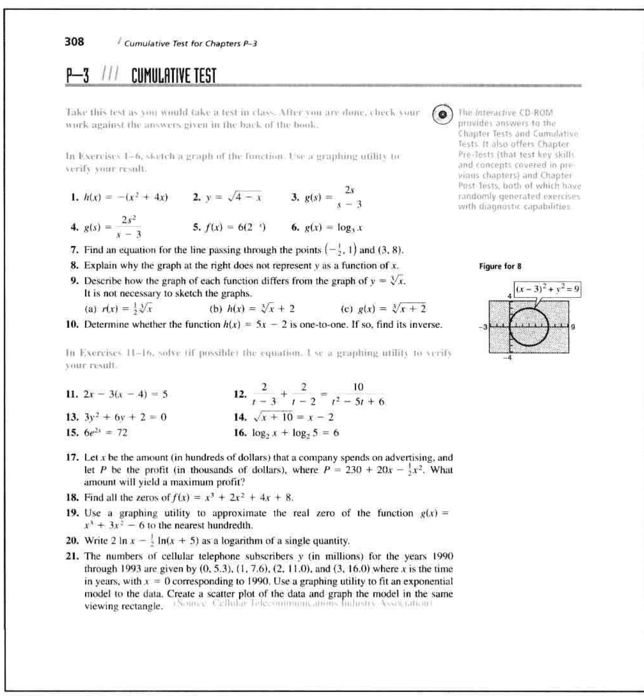
In Exercises 11 and 12, use a graphing utility to graph the function. If the function is periodic, find its period.

11. $y = \sin 2\pi x + 2\cos \pi x$ 12. $y = 6e^{-0.12t}\cos(0.25t),\ 0 \le t \le 32$

13. Find $a$, $b$, and $c$ for the function $f(x) = a\sin(bx + c)$ so that the graph of $f$ matches the figure.
14. Find the exact value of $\tan\left(\arccos\frac{2}{3}\right)$ without the aid of a calculator.
15. Graph the function $f(x) = 2\arcsin\left(\frac{1}{2}x\right)$.
16. A ship leaves port at noon and sails at a speed of 18 knots. Its bearing is N 16° W. If the port is positioned at the origin, determine the coordinates of the position of the ship at 3 P.M.

Figure for 13




308 / Cumulative Test for Chapters P–3

P–3 /// CUMULATIVE TEST

Take this test as you would take a test in class. After you are done, check your work against the answers given in the back of the book.

The *Interactive* CD-ROM provides answers to the Chapter Tests and Cumulative Tests. It also offers Chapter Pre-Tests (that test key skills and concepts covered in previous chapters) and Chapter Post-Tests, both of which have randomly generated exercises with diagnostic capabilities.

In Exercises 1–6, sketch a graph of the function. Use a graphing utility to verify your result.

1. $h(x) = -(x^2 + 4x)$ 2. $y = \sqrt{4 - x}$ 3. $g(s) = \dfrac{2s}{s - 3}$
4. $g(s) = \dfrac{2s^2}{s - 3}$ 5. $f(x) = 6(2^{-x})$ 6. $g(x) = \log_3 x$
7. Find an equation for the line passing through the points $\left(-\frac{1}{2}, 1\right)$ and (3, 8).
8. Explain why the graph at the right does not represent $y$ as a function of $x$.
9. Describe how the graph of each function differs from the graph of $y = \sqrt[3]{x}$. It is not necessary to sketch the graphs.
(a) $r(x) = \frac{1}{2}\sqrt[3]{x}$ (b) $h(x) = \sqrt[3]{x} + 2$ (c) $g(x) = \sqrt[3]{x + 2}$
10. Determine whether the function $h(x) = 5x - 2$ is one-to-one. If so, find its inverse.

Figure for 8



In Exercises 11–16, solve (if possible) the equation. Use a graphing utility to verify your result.

11. $2x - 3(x - 4) = 5$ 12. $\dfrac{2}{t - 3} + \dfrac{2}{t - 2} = \dfrac{10}{t^2 - 5t + 6}$
13. $3y^2 + 6y + 2 = 0$ 14. $\sqrt{x + 10} = x - 2$
15. $6e^{2x} = 72$ 16. $\log_2 x + \log_2 5 = 6$

17. Let $x$ be the amount (in hundreds of dollars) that a company spends on advertising, and let $P$ be the profit (in thousands of dollars), where $P = 230 + 20x - \frac{1}{2}x^2$. What amount will yield a maximum profit?
18. Find all the zeros of $f(x) = x^3 + 2x^2 + 4x + 8$.
19. Use a graphing utility to approximate the real zero of the function $g(x) = x^3 + 3x^2 - 6$ to the nearest hundredth.
20. Write $2\ln x - \frac{1}{2}\ln(x + 5)$ as a logarithm of a single quantity.
21. The numbers of cellular telephone subscribers $y$ (in millions) for the years 1990 through 1993 are given by (0, 5.3), (1, 7.6), (2, 11.0), and (3, 16.0) where $x$ is the time in years, with $x = 0$ corresponding to 1990. Use a graphing utility to fit an exponential model to the data. Create a scatter plot of the data and graph the model in the same viewing rectangle. (Source: Cellular Telecommunications Industry Association)

**Chapter Tests** Each chapter that is not followed by a Cumulative Test ends with a Chapter Test, an effective tool for student self-assessment.

**Cumulative Tests** The Cumulative Tests that follow Chapters 3, 6, and 10 help students judge their mastery of previously covered material as well as reinforce the knowledge they have been accumulating throughout the text—preparing them for other exams and for future courses.

# Supplements

*Precalculus Functions and Graphs: A Graphing Approach,* Second Edition, by Larson, Hostetler, and Edwards is accompanied by a comprehensive supplements package. Most items are keyed to the text.

## Printed Resources

### For the student

***Study and Solutions Guide*** by Bruce Edwards, University of Florida, and Dianna L. Zook, Indiana University—Purdue University at Fort Wayne

- Section summaries of key concepts
- Detailed, step-by-step solutions to all odd-numbered exercises
- Key solution steps for Chapter Tests and Cumulative Tests
- Practice tests with solutions
- Study strategies

***Graphing Technology Guide***

- Keystroke instructions for a wide variety of Texas Instruments, Casio, Sharp, and Hewlett-Packard graphing calculators—including the most current models.
- Examples with step-by-step solutions
- Extensive graphics screen output
- Technology tips

### For the instructor

***Instructor's Annotated Edition***

- Includes the entire student edition of the text, with the student answers section
- Instructor's Answers section: Answers to all even-numbered exercises, and answers to all Explorations, Technology exercises, Group Activities, and Chapter Project exercises
- Annotations at point of use offer specific teaching strategies and suggestions for implementing Group Activities, point out common student errors, and give additional examples, exercises, class activities, and group activities.

***Solutions to Even-Numbered Exercises***

- Detailed, step-by-step solutions to even-numbered exercises

***Test Item File and Instructor's Resource Guide***

- Printed test bank with approximately 2000 test items (multiple-choice, open-ended, and writing) coded by level of difficulty
- Technology-required test items coded for easy reference
- Bank of chapter test forms with answer keys

- Two final exam test forms
- Notes to the instructor, including materials for alternative assessment and managing the multicultural and cooperative-learning classrooms

***Problem Solving, Modeling, and Data Analysis Labs*** by Wendy Metzger, Palomar College

- Multipart, guided discovery activities and applications
- Keystroke instructions for Derive and *TI-82*
- Keyed to the text by topic
- Funded in part by NSF (National Science Foundation, Instrumentation and Laboratory Improvement) and California Community College Fund for Instructional Improvement

## Media Resources

### For the student

***Interactive Precalculus Functions and Graphs: A Graphing Approach; A Self-Guided Study Companion*** (See pages xviii–xx for a description, or visit the Houghton Mifflin home page at http://www.hmco.com for a preview.)

- Interactive, multimedia CD-ROM format
- IBM-PC for Windows

***Tutor software***

- Interactive tutorial software keyed to the text by section
- Diagnostic feedback
- Chapter self-tests
- Guided exercises with step-by-step solutions
- Glossary

***Videotapes*** by Dana Mosely

- Comprehensive, text-specific coverage keyed to the text by section
- Real-life application vignettes introduced where appropriate
- Computer-generated animation
- For media/resource centers
- Additional explanation of concepts, sample problems, and applications
- Instructional graphing calculator videotape also available

### For the instructor

***Computerized Testing (IBM, Macintosh, Windows)***

- New on-line testing
- New grade-management capabilities
- Algorithmic test-generating software provides an unlimited number of tests
- Approximately 2000 test items
- Also available as a printed test bank

***Transparency Package***

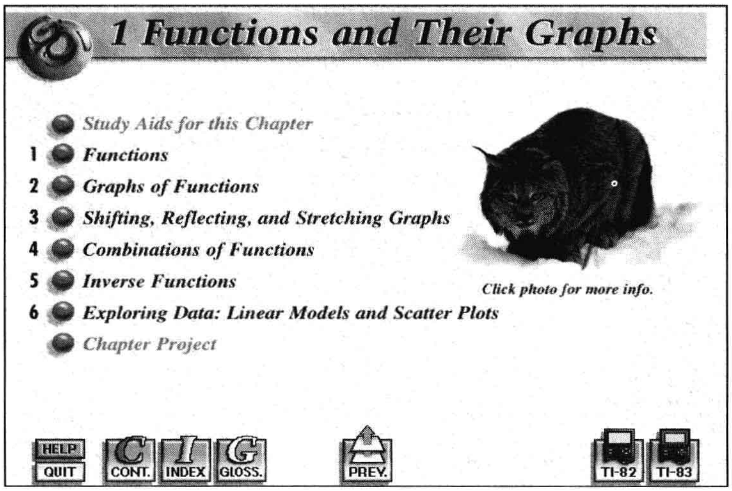
- 70 color transparencies color-coded by topic

## Interactive Precalculus Functions and Graphs: A Graphing Approach

To accommodate a variety of teaching and learning styles, *Precalculus Functions and Graphs: A Graphing Approach; A Self-Guided Study Companion* is also available in a multimedia, CD-ROM format. In this interactive format, the text offers the student additional tutorial assistance with

- Complete solutions to all odd-numbered text exercises.
- Chapter pre-tests, self-tests, and post-tests.
- *TI-82* and *TI-83* emulators.
- Guided examples with step-by-step solutions.
- Editable graphs.
- Animations of mathematical concepts.
- Section and tutorial exercises.
- Glossary of key terms.

These and other pedagogical features of the CD-ROM are illustrated by the screen dumps shown below.




**Chapter Topics** Each chapter begins with an outline of the topics to be covered. Using the buttons at the bottom of the screen, the student can quickly move to the appropriate section.

**Introductory Chapter Application** Each chapter opens with a real-data application that illustrates the key concepts and techniques to be covered. Clicking on the photo, the student can access additional data and background information that frames the real-world context for a mathematical concept.

**Chapter Project** Each chapter is accompanied by a Chapter Project. This offers the student the opportunity to synthesize the algebraic techniques and concepts studied in the chapter. Many projects use real data and emphasize data analysis and mathematical modeling.

**Study Aids** Each section offers the student an array of additional study aids, including Chapter Pre-, Post-, and Self-Tests, Review Exercises, and Focus on Concepts. With diagnostics, complete solutions, or answers, these helpful features promote the focused practice needed to master mathematical concepts. Short, informative video segments are also included.