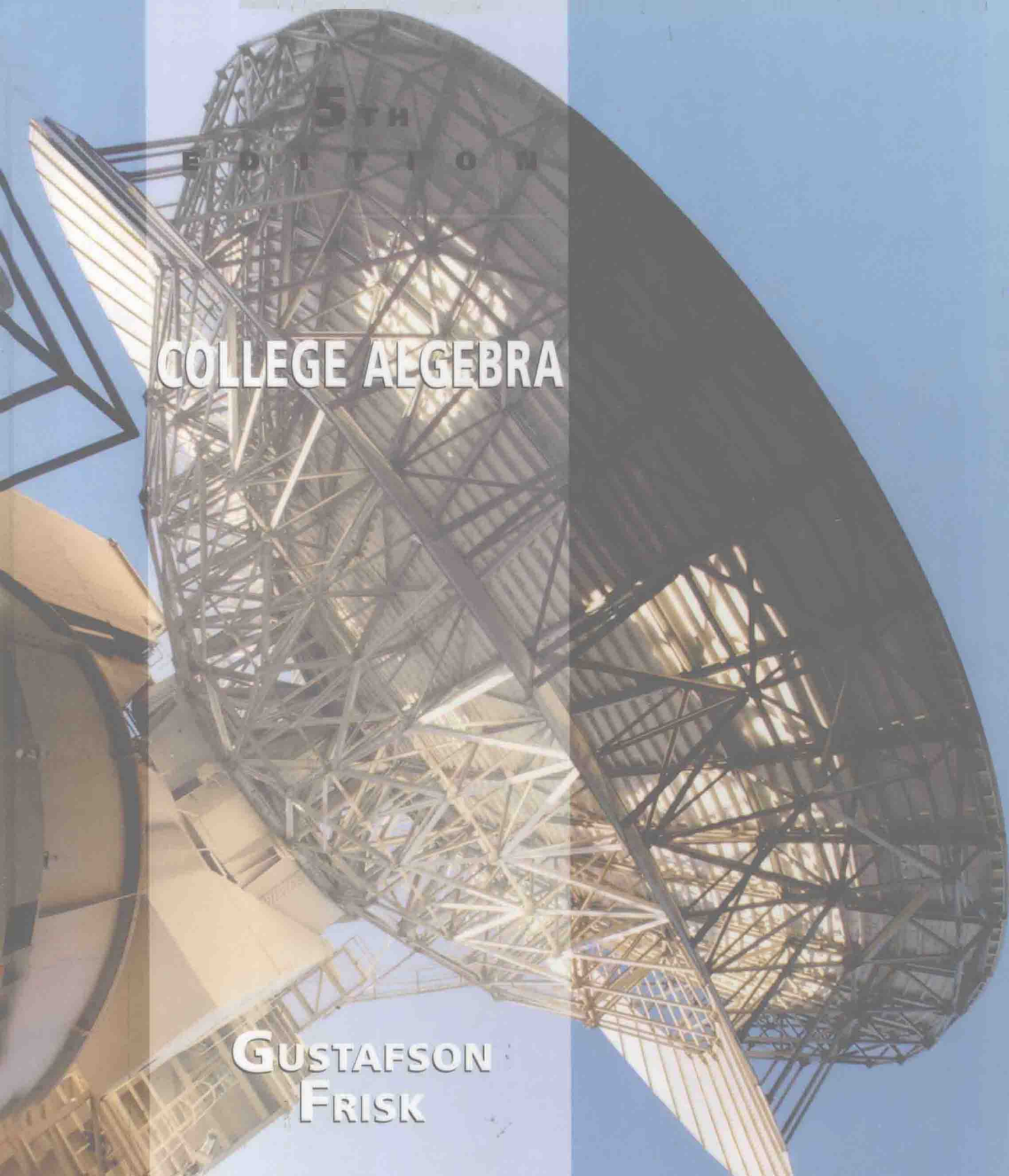

5TH EDITION

COLLEGE ALGEBRA

GUSTAFSON
FRISK

5TH
EDITION

COLLEGE ALGEBRA

R. David Gustafson
Peter D. Frisk

Rock Valley College

Brooks/Cole Publishing Company
Pacific Grove, California

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About the Cover: Located at the Jamesburg Earth Station in Cachagua, California, this Philco Ford satellite antenna was built in 1968 by the U.S. government for its space program. The dish, now owned by AT&T, is 97 feet in diameter and houses an 8-foot hyperboloid in its center (see back cover). Unlike domestic communication antennae, which use linear polarization signals, this antenna creates a circular polarization signal for international use. The signal is directed to the hyperboloid, bounces back to the paraboloid, and then is beamed to a satellite. The signal has a maximum strength of 10^{10} watts of power or 100 dbw. There are currently only 10 satellite antennae of this class operating in the U.S.

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PREFACE

TO THE INSTRUCTOR

College Algebra has been extensively revised in this fifth edition. This revision was motivated by the need to prepare students better for the mathematics of the next century.

Although the changes have been substantial, our fundamental philosophy as teachers remains the same. Consequently, the goal of this book remains unchanged: to hold attrition to a minimum and prepare students to succeed at the next stage, whether it is trigonometry, precalculus, statistics, liberal arts mathematics, or everyday life.

We believe that this fifth edition accomplishes this goal through a successful blending of content and pedagogy. We present comprehensive, in-depth, precise coverage of the topics of college algebra, incorporated into a framework of tested teaching strategy and combined with carefully selected pedagogical features.

Changes for the Fifth Edition

The overall effects of the changes we have made in the fifth edition have been as follows.

- To increase the emphasis on learning mathematics through graphing. Although graphing calculators are incorporated throughout the book, their use is not required. All of the topics are fully discussed in traditional ways. Of course, we recommend that instructors try the graphing calculator material.

- To increase the emphasis on problem solving through realistic applications. The variety of applications problems has been increased significantly, and all application problems are now labeled with special headings.
- To fine-tune the presentation of certain topics for better flow of ideas and for clarity.
- To increase the visual interest by the use of a four-color format. We continue to use color not just as a design feature, but in a functional way. Color is still used to highlight terms that you would point to in a classroom discussion.

Some of the specific changes made to chapters are listed below.

1. Chapter 1, which is mainly review, has been condensed so that instructors can get to college algebra topics more quickly. The work on complex numbers has been moved to Chapter 2, after a discussion of quadratic equations. Finding solutions of quadratic equations now provides the motivation for discussing complex numbers.
2. Chapter 2, dealing with equations and inequalities, has been reorganized. It now incorporates much of the work with inequalities, rational inequalities, and absolute value. The applications sections have been extensively revised to provide more authentic and varied applied problems.
3. The fourth edition's Chapter 3 has been divided into two chapters. Chapter 3 now deals with graphing lines, slope, writing equations of lines, general graphing of other relations, and ratio and proportion. Graphing calculators are introduced in Chapter 3.
4. Chapter 4 deals with the more formal aspects of functions and their inverses. A new section on translations of graphs has been added.
5. Chapter 5 now deals with the remainder and factor theorems, synthetic division, and finding rational roots of polynomial equations. After a brief discussion of the bisection method, graphing calculators are used to find approximations for irrational roots of polynomial equations.
6. Chapter 6 now deals with logarithms. Coverage of this topic has been thoroughly revised to obtain a better flow of ideas. Many more application problems have been added.
7. Chapter 7 now deals with systems of linear equations. Graphing calculators are used to enhance the discussion of solving systems by graphing. The application problems have been thoroughly revised and made more relevant. Matrix methods continue to be emphasized. The material on graphing linear inequalities in two variables has been included in the section that covers systems of linear inequalities. A separate section on linear programming is now included.
8. Chapter 8 deals with conic sections and quadratic systems. This chapter now contains more application problems.

The following are some of the specific pedagogical changes.

1. Cumulative review exercises have been added after every three chapters.
2. Warning! Students are now warned about common errors by a special symbol.

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3. All sections are now divided into subsections with headings. When a section deals with more than one topic, the headings will help students focus on each specific topic.

4. All exercises requiring scientific calculators are marked with a special logo.

All exercises requiring graphing calculators are marked with a different logo.

At the same time, we have kept the pedagogical features that made previous editions of the book so successful, as outlined in the paragraphs that follow.

Solid Mathematics The treatment of college algebra is direct and straightforward. Although the treatment is mathematically sound, it is not so rigorous that it will confuse students. Every effort has been made to ensure the accuracy of the mathematics and of the answers to the exercises. The book has been critiqued by dozens of reviewers. Each author and a problem checker have worked every exercise. Although the exercise sets are designed primarily to provide practice and drill, they also contain problems that will challenge the best students. The book contains over 4000 exercises.

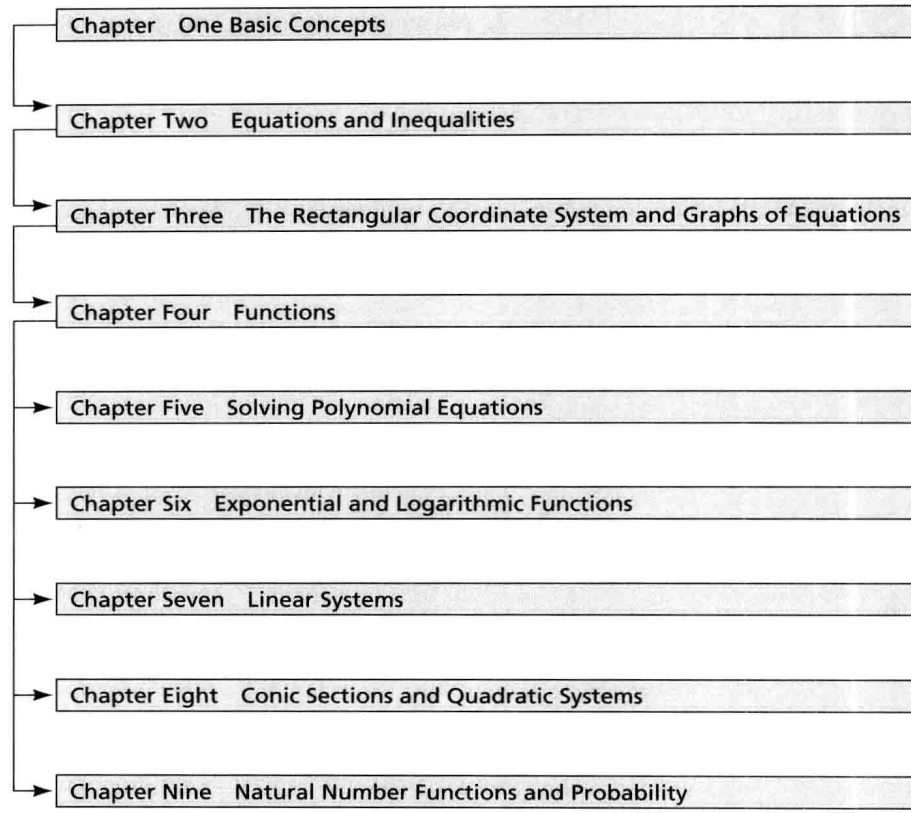
Accessibility to Students The book is written for students to read and understand. The numerous problems within each exercise set are carefully keyed to over 400 worked examples, in which author's notes explain many of the steps used in the problem-solving process. In the student edition, Appendix III contains the answers to the odd-numbered exercises, as well as all answers to the chapter review exercises, chapter tests, and cumulative review exercises. In the instructor's edition, Appendix III provides the answers to all exercises.

Review is incorporated into the book in many ways: There are chapter summaries, review exercises at the end of each chapter, cumulative review exercises at the end of every three chapters, and endpapers that list (in order of presentation) the important formulas developed in the book.

Emphasis on Applications To show that mathematics is useful, we include a large number of word problems and applications throughout the book.

Organization and Coverage

The book can be used in a variety of ways. For optimum flexibility, many of the chapters have been designed to be sufficiently independent that you can pick and choose topics that are relevant to your students' needs. The accompanying diagram shows how the chapters are interrelated.



Calculators and Computers

The use of calculators is assumed throughout the book. We believe that students should learn calculator skills in the mathematics classroom. They will then be prepared to use calculators in science and business classes and for nonacademic purposes. The directions within each exercise set indicate which exercises require calculators.

After much deliberation, we decided not to give keystrokes for any specific model of graphing calculator. Several manufacturers told us that they will soon be introducing new models that have different keystrokes from the models currently available. We do not want to confuse students by giving obsolete keystrokes. Instead, the book covers the features that are common to all graphing calculators.

Features of This Edition

EXAMPLE 1

a. $4^2 = 4 \cdot 4 = 16$ Read 4^2 as "four squared."

b. $(-4)^2 = (-4)(-4) = 16$

c. $-4^2 = -(4 \cdot 4) = -16$

d. $(5)^3 = 5 \cdot 5 \cdot 5 = 125$ Read 5^3 as "five cubed."

e. $(-5)^3 = (-5)(-5)(-5) = -125$

f. $3x^4 = 3 \cdot x \cdot x \cdot x \cdot x$ Read x^4 as "x to the fourth power."

g. $(3x)^4 = (3x)(3x)(3x)(3x) = 81x^4$ ■

Warning! It is important to note the distinction between ax^n and $(ax)^n$, and between $-x^n$ and $(-x)^n$:

$$ax^n = a \cdot \overbrace{x \cdot x \cdot x \cdot \cdots \cdot x}^{n \text{ factors of } x} \qquad (ax)^n = \overbrace{(ax)(ax)(ax) \cdot \cdots \cdot (ax)}^{n \text{ factors of } ax}$$

$$-x^n = -\overbrace{(x \cdot x \cdot x \cdot \cdots \cdot x)}^{n \text{ factors of } x} \qquad (-x)^n = \overbrace{(-x)(-x)(-x) \cdot \cdots \cdot (-x)}^{n \text{ factors of } -x}$$

Rules of Exponents

We begin to develop the rules of exponents by considering the product $x^m x^n$. Because x^m indicates that x is to be used as a factor m times and because x^n indicates that x is to be used as a factor n times, there are $m + n$ factors of x in the product $x^m x^n$.

$$x^m x^n = \overbrace{\overbrace{x \cdot x \cdot x \cdot \cdots \cdot x}^{m \text{ factors of } x} \cdot \overbrace{x \cdot \cdots}^{n \text{ factors of } x}}^{m+n \text{ factors of } x}$$

Thus, to multiply exponential expressions v
add the exponents.

The Product Rule of Exponents

If m and n are natural numbers, then

$$x^m x^n = x^{m+n}$$

Warning! The product rule app
the same base. A product of two p
cannot be simplified.

To find another property of exponents,
$(x^m)^n$. The exponent n indicates that x^m is t
that x is to be used as a factor mn times.

$$(x^m)^n = \overbrace{(x^m)(x^m)(x^m) \cdot \cdots \cdot (x^m)}^{n \text{ factors of } x^m}$$

4.2 EXERCISES

In Exercises 1–8, graph each quadratic equation.

1. $y = x^2 - x$
2. $y = x^2 + 2x$
3. $y = -3x^2 + 2$
4. $y = -3x^2 + 4$
5. $y = -\frac{1}{2}x^2 + 3$
6. $y = \frac{1}{2}x^2 - 2$
7. $y = x^2 - 4x + 1$
8. $y = -x^2 - 4x + 1$

In Exercises 9–16, find the vertex of each parabola.

9. $y = x^2 - 1$
10. $y = -x^2 + 2$
11. $y = x^2 - 4x + 4$
12. $y = x^2 - 10x + 25$
13. $y = x^2 + 6x - 3$
14. $y = -x^2 + 9x - 2$
15. $y = -2x^2 + 12x - 17$
16. $y = 2x^2 + 16x + 33$

In Exercises 17–30, find each maximum.

17. ***Architecture*** A parabolic arch has an equation of $x^2 + 20y - 400 = 0$, where x is measured in feet. Find the maximum height of the arch.

18. ***Ballistics*** An object is thrown from the origin of a coordinate system with the x-axis along the ground and the y-axis vertical. Its path, or **trajectory**, is given by the equation $y = 400x - 16x^2$. Find the object's maximum height.

19. ***Ballistics*** A child throws a ball up a hill that makes an angle of 45° with the horizontal. The ball lands 100 feet up the hill. Its trajectory is a parabola with equation $y = -x^2 + ax$ for some number a. Find a. (See Illustration 1.)

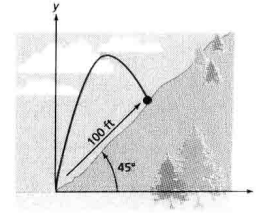


ILLUSTRATION 1

20. ***Maximizing area*** The rectangular garden in Illustration 2 has a width of x and a perimeter of 100 feet. Find x so that the area of the rectangle is maximum.

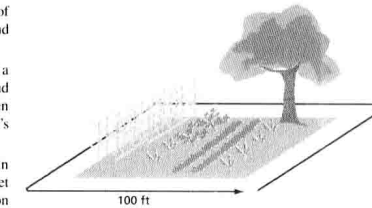


ILLUSTRATION 2

21. ***Maximizing storage area*** A farmer wants to partition a rectangular feed-storage area in a corner of his barn. The barn walls form two sides of the stall, and the farmer has 50 feet of partition for the remaining two sides. What dimensions will maximize the area? (See Illustration 3.)

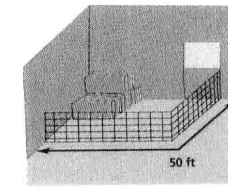


ILLUSTRATION 3

◀ Warnings to students are highlighted.

◀ Sections are divided into subsections.

All definitions and theorems are clearly boxed. ▶

Application problems have been extensively revised and updated. ▶

All art has been redrawn. ▶

Each application has a title. ▶

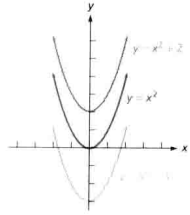
4.4 TRANSLATING AND STRETCHING GRAPHS

■ Vertical and Horizontal Translations ■ Vertical and Horizontal Stretchings

■ Vertical and Horizontal Translations

The graphs of different equations may be identical except for their position in the xy-plane. For example, Figure 4-18(a) shows the graph of the function $y = x^2 + k$ for three different values of k. The graph of $y = x^2 + 2$ is identical to the graph of $y = x^2$ except that it is shifted 2 units upward. Similarly, the graph of $y = x^2 - 3$ is identical to the graph of $y = x^2$ except that it is shifted 3 units downward. Such shifts are called **vertical translations**.

Figure 4-18(b) shows the graph of the equation $y = (x + h)^2$ for three different values of h. The graph of $y = (x - 2)^2$ is identical to the graph of $y = x^2$ except that it is shifted 2 units to the right. The graph of $y = (x + 3)^2$ is identical to the graph of $y = x^2$ except that it is shifted 3 units to the left. Such shifts are called **horizontal translations**.

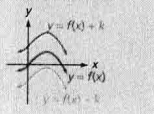


(a)

FIGUR

In general, we can make the following

Vertical Translations



If f is a function and k is a positive numb

- The graph of $y = f(x) + k$ is identical translated k units upward.
- The graph of $y = f(x) - k$ is identical translated k units downward.

◀ A new section on translations has been included.

Many summary boxes have been added. ▲

Graphing calculators are included often to illustrate mathematical concepts. ▶

Calculator exercises are marked clearly with either a calculator logo or a graphing calculator logo. ▶

We substitute 5 for x and calculate I.

$$I = 12(0.6)^5$$
$$I \approx 0.93312$$

At a depth of 5 meters, the intensity of the light is slightly less than 1, or about one-twelfth of the intensity at the surface. ■

■ Watching Money Grow

EXAMPLE 8 If \$1 is deposited in an account earning 9% annual interest, compounded monthly, estimate how much will be in the account in 70 years.

Solution We can substitute 1 for A_0, .09 for r, and 12 for k into the formula

$$A = A_0\left(1 + \frac{r}{k}\right)^{kt}$$

and simplify to get

$$A = (1.0075)^{12t}$$

We now use a graphing calculator to see how the money grows year by year. We graph the function $A = (1.0075)^{12t}$ in the viewing window $0 \le t \le 100$ and $0 \le A \le 750$ to obtain the graph shown in Figure 6-5. We can then use the TRACE and ZOOM features to estimate that \$1 grows to the surprising amount of approximately \$532 in 70 years. ■

FIGURE 6-5

6.1 EXERCISES

In Exercises 1–4, find each value to four decimal places.

1. $4^{\sqrt{3}}$ **2.** $5^{\sqrt{2}}$ **3.** 7^{π} **4.** $3^{-\pi}$

In Exercises 5–12, graph each exponential function.

5. $y = 3^x$ **6.** $y = 5^x$ **7.** $y = \left(\frac{1}{5}\right)^x$ **8.** $y = \left(\frac{1}{3}\right)^x$

9. $y = -2^x$ **10.** $y = -3^x$ **11.** $y = \left(\frac{3}{4}\right)^x$ **12.** $y = \left(\frac{4}{3}\right)^x$

In Exercises 13–28, graph each function.

13. $y = 3^x - 1$ **14.** $y = 2^x + 3$ **15.** $y = 2^x + 1$ **16.** $y = 4^x - 4$

17. $y = 3^{x-1}$ **18.** $y = 2^{x-3}$ **19.** $y = 3^{x+1}$ **20.** $y = 2^{x-3}$

21. $y = 2^{x+1} - 2$ **22.** $y = 3^{x-1} + 2$ **23.** $y = 3^{x-2} + 1$ **24.** $y = 3^{x+2} - 1$

25. $y = 5(2^x)$ **26.** $y = 2(5^x)$ **27.** $y = 3^{-x}$ **28.** $y = 2^{-x}$

6.2 BASE-e EXPONENTIAL FUNCTIONS

■ Graphing the Exponential Function ■ Applications of Exponential Functions ■ The Malthusian Theory

Leonhard Euler (1707–1783)
Euler first used the letter i to represent $\sqrt{-1}$, the letter e for the base of natural logarithms, and the symbol Σ for summation. Euler was one of the most prolific mathematicians of all time, contributing to almost all areas of mathematics. Much of his work was accomplished after he became blind.

In mathematical models of natural events, the number $e = 2.71828182845904\ldots$ appears often as the base of an exponential function. We introduce this important number by recalling the formula for compound interest,

$$A = A_0\left(1 + \frac{r}{k}\right)^{kt}$$

and allowing k, representing the number of compounding periods per year, to become very large. To see what happens, we let $k = rp$, where p is a new variable.

$$A = A_0\left(1 + \frac{r}{k}\right)^{kt}$$

$$A = A_0\left(1 + \frac{r}{rp}\right)^{rpt} \quad \text{Substitute } rp \text{ for } k.$$

$$A = A_0\left(1 + \frac{1}{p}\right)^{rpt} \quad \text{Simplify } \frac{r}{rp}.$$

$$A = A_0\left[\left(1 + \frac{1}{p}\right)^{p}\right]^{rt} \quad \text{Remember that } (a^m)^n = a^{mn}.$$

Because the annual r
becomes very large, ther
becomes tied to the ques

$$\left(1 + \frac{1}{p}\right)^{p}$$

as p becomes very large
Some results calculat

CUMULATIVE REVIEW EXERCISES

In Cumulative Review Exercises 1–4, decide whether each equation defines a function.

1. $x = 3x - 1$ **2.** $y = x^2 + 3$ **3.** $y = \frac{1}{x - 2}$ **4.** $y^2 = 4x$

In Cumulative Review Exercises 5–8, find the domain and range of each function.

5. $y =$

In Cum

9. $y =$

In Cum

11. $y =$

In Cum

15. $y =$

In Cum

17. $(f$

In Cum

21. $(f$

4 CHAPTER TEST

In Questions 1–2, find the domain and range of each function.

1. $f(x) = \frac{3}{x - 5}$ **2.** $f(x) = \sqrt{x + 3}$

In Questions 3–4, find $f(-1)$ and $f(2)$.

3. $f(x) = \frac{x}{x - 1}$ **4.** $f(x) = \sqrt{x + 7}$

In Questions 5–8, find the vertex of each parabola.

5. $y = 3(x - 7)^2 - 3$ **6.** $y = x^2 - 2x - 3$

7. $y = 3x^2 - 24x + 38$ **8.** $y = 5 - 4x - x^2$

In Questions 9–10, graph each polynomial function.

9. $y = x^4 - x^2$ **10.** $y = x^5 - x^3$

In Questions 11–12, assume that an object tossed vertically upward reaches a height of h feet after t seconds, where $h = 100t - 16t^2$.

11. In how many seconds does the object reach its maximum height?

12. What is that maximum height?

13. ***Suspension bridge*** The cable of a suspension bridge is in the shape of the parabola $x^2 - 2500y + 25{,}000 = 0$ in the coordinate system shown in Illustration 1. Distances are in feet. How far above the roadway is the cable's lowest point?

14. Refer to Question 13. How far above the roadway does the cable attach to the vertical pillars?

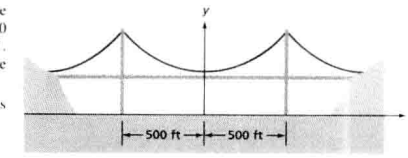


ILLUSTRATION 1

- Sections are divided into subsections.
- Historical notes appear throughout the text.
- Color is used in a functional way.
- Author's notes explain steps.

Sample Chapter Tests and Cumulative Review Exercises have been added.

Topics Covered

Review Chapters 1 and 2 review topics from basic algebra—the real number system, exponents and radicals, polynomial arithmetic, solutions of linear and quadratic equations, complex numbers, radical equations, inequalities, and absolute value.

Inequalities Inequalities with one variable are now discussed in Chapter 2. Rational inequalities are solved by both the test-point and sign-graph methods. Inequalities with two variables, along with their graphical interpretations, are covered in Chapter 7, before discussing systems of inequalities.

Functions The concept of the rectangular coordinate system is introduced in Chapter 3, with emphasis on graphing lines, writing equations of lines, and graphing various relations. Graphing calculators are also introduced in Chapter 3.

Translations of graphs and the more formal aspects of functions, function notation, rational functions, algebra of functions, composition of functions, and inverse functions are now covered in Chapter 4.

Roots of Polynomial Equations Chapter 5 discusses methods for finding rational roots of polynomial equations. Several examples illustrate the interplay between the fundamental theorem of algebra, Descartes' rule of signs, the remainder and factor theorems, the rational-root theorem, and the conjugate-pairs result. The bisection method is briefly discussed before graphing calculators are used to find irrational roots.

Exponential and Logarithmic Functions Chapter 6 covers exponential functions and logarithms and many of their applications. The use of calculators is emphasized in this chapter.

Systems of Equations and Inequalities Chapter 7 includes techniques for solving systems of linear equations. Matrix methods are developed, and some matrix algebra is presented. Linear programming using graphical methods has been expanded into a complete section. The topic of partial fractions is introduced as an application of systems of linear equations.

Conic Sections Chapter 8 develops the basic forms of the equations for conic sections and provides opportunities for graphing these equations. Solutions of simultaneous second-degree equations are obtained both graphically and algebraically.

Natural Number Functions and Probability The binomial theorem, permutations, and combinations lead to a presentation of simple and compound probabilities, odds, and mathematical expectation. The chapter includes an introduction to mathematical induction. An induction proof of the binomial theorem is given in Appendix I.

Ancillaries for the Instructor

Instructor's Edition The *Instructor's Edition* contains an expanded answer section, which includes the answers for *all exercises in the text.*

Test Manual **Teresa Bittner** The *Test Manual* contains three ready-to-use forms of every chapter test. Answer keys are also provided.

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Computer Testing Software

Available with our text are two extensive electronic question banks, one short-answer and one multiple-choice. Each form contains approximately 1700 test items and is available for IBM-compatible and Macintosh computers. The testing program gives you all the features of state-of-the-art word processors and more, including the ability to see all technical symbols, fonts, and formatting on the screen just the way they will appear when printed. The question banks can be edited.

EXPTEST™ runs on IBM and compatible computers.

ExamBuilder™ runs on Macintosh computers.

Transparencies

Transparencies of 37 key graphics from the text are available to assist the instructor in the classroom.

Videos
Educational Video Resources

A complete set of videos, produced by Educational Video Resources, is available upon adoption of the text.

Ancillaries for the Student

Study Guide
George Grisham

For each chapter in the text, the *Study Guide* contains a message to the student, completely worked examples for each section, additional exercises, cautions and hints, and completely worked solutions for selected odd-numbered exercises from the text. Available for sale to students.

Student Solutions Manual
Michael Welden

The *Student Solutions Manual* provides worked-out solutions for every odd-numbered exercise in the text. Available for sale to students.

Visual Precalculus
David Schneider

This fun-to-use software for IBM and compatible computers is customized to the text. *Visual Precalculus* uses animation to explore relevant exercises and examples from the text. A mouse is optional. A *Student User's Guide* accompanies the software. Available for sale to students. Site licenses are also available for sale.

Graphing Calculator Activities for Algebra
Miller, Perry, and Tveten

Graphing Calculator Activities for Algebra provides instruction, problems, exploratory exercises, and projects, plus instruction and keystrokes for using the TI-81 and Casio 7700 graphing calculators. Available for sale to students.

TO THE STUDENT

Congratulations. You now own a state-of-the-art textbook that has been written especially for you. We, the authors, have tried to write a book that you can read and understand. The book is carefully written and includes an extensive number of worked examples. However, if you intend to get the most out of your algebra course, you must read and study the textbook properly. We recommend that you work the

examples on paper and be sure that you understand them before attempting to work the exercises.

A *Student Solutions Manual* is available for sale, containing worked-out solutions to all of the odd-numbered exercises. Also available for sale is a *Student Study Guide*, designed to enhance your study techniques.

The material presented in *College Algebra*, 5th edition, will be of value to you in later years. Therefore, we suggest that you keep this book after completing the course. It will be a good source of reference and will keep at your fingertips the material that you have learned here.

We wish you well.

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