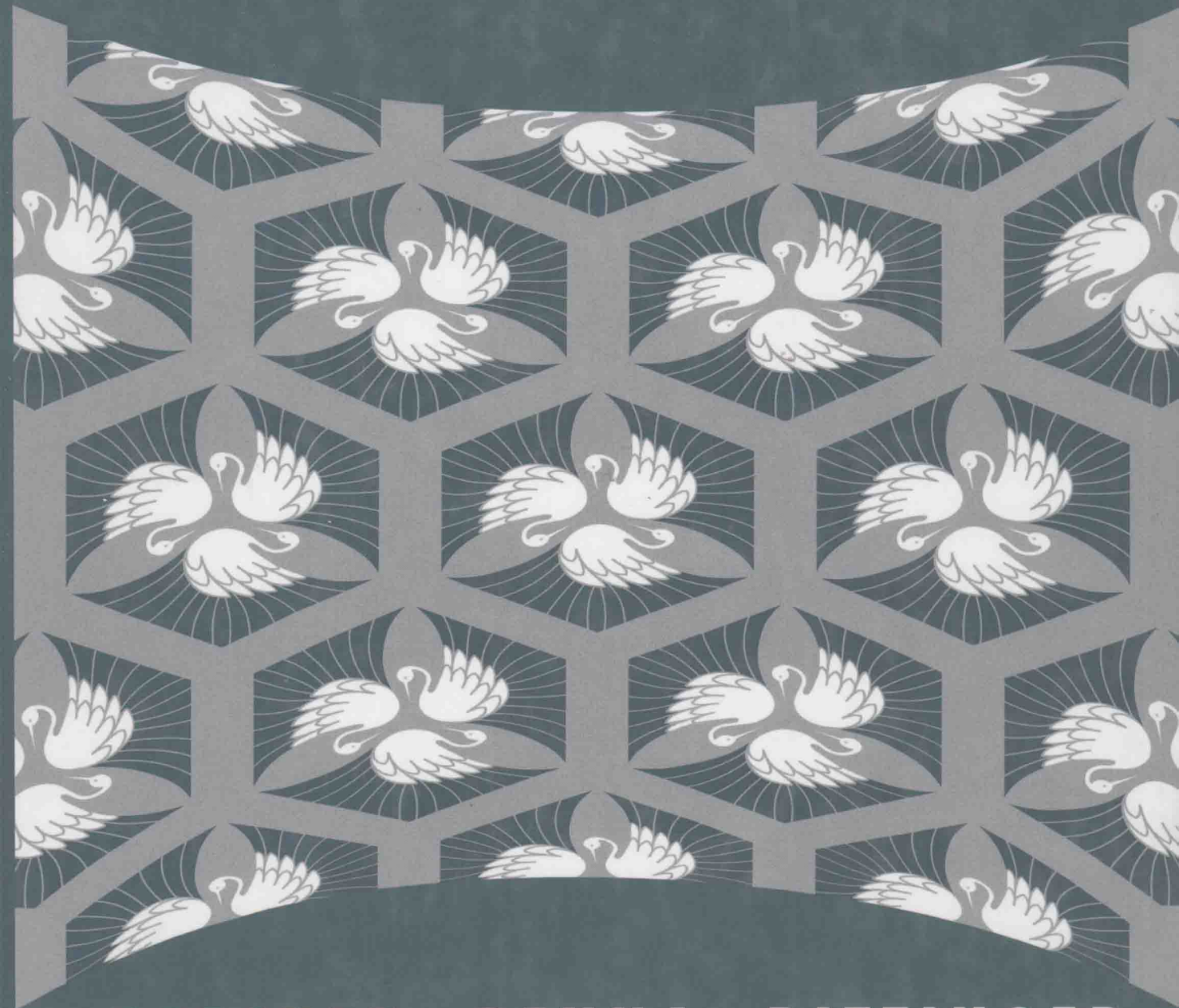# COLLEGE ALGEBRA

FOURTH EDITION

BEECHER   PENNA   BITTINGER

College Algebra

College Algebra

4th EDITION

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Preface

In writing this textbook we challenged ourselves to do everything possible to help you learn the concepts and skills contained between its covers so that you will be successful in this course and in the mathematics courses you take in the future. Every feature we have included was done with this in mind. We realize that your time is both valuable and limited, so we communicate in a highly visual way that allows you to focus easily and learn quickly and efficiently. We feel confident that, if you are willing to invest an adequate amount of your time in the learning process, this text will be of great value to you.

Best wishes for a positive learning experience,
Judy Beecher
Judy Penna
Marv Bittinger

This *College Algebra* textbook is known for enabling students to "see the math" through its focus on visualization, early introduction to functions, and making connections between math concepts and the real world. Additional information is presented on these themes in the pages that follow.

With the new edition, we continue to innovate by incorporating more ongoing review to help students develop understanding and study effectively. We have new Mid-Chapter Mixed Review exercise sets to give students an extra opportunity to master concepts and new Study Guides which provide built-in tools to help prepare for tests. Specific content changes to the Fourth Edition are outlined below.

MyMathLab® has been expanded so that the online content is even more integrated with the text's approach, with the addition of Vocabulary, Synthesis, and Mid-Chapter Mixed Review exercises from the text as well as example-based videos that we created.

Our overarching goal is to provide students with a learning experience that will not only lead to success in this course but also prepare them to be successful in the mathematics courses they take in the future.

▶ Content Changes to the Fourth Edition

In this Fourth Edition, we have changed the table of contents to make the material at the beginning of the text more easily taught and learned. We have balanced and evened out the lengths of Chapters 1–3 in the Third Edition by presenting the material in four chapters in the Fourth Edition.

By spreading this material out over four chapters and presenting it in a different order, we provide the student with a more even-handed and consistent introduction to College Algebra. The new arrangement is well suited to a one-section-per-lecture class format. We think students and instructors alike will be pleased with the changes that have been made.

- The material on increasing, decreasing, and piecewise functions, along with the discussion of the algebra of functions, composition of functions, and symmetry and transformations that was in Chapter 1 in the Third Edition, has been moved to a separate chapter (Chapter 2) in the Fourth Edition.

- The algebra of functions and composition of functions are now presented in two sections rather than one.
- The material on linear equations, linear functions, and linear inequalities has been moved from Chapter 2 in the Third Edition, to Chapter 1 in the Fourth Edition, where functions are introduced.
- The chapter on polynomial functions and rational functions has been shortened by moving the section on variation to Chapter 2 in the Fourth Edition.
- The discussion of equations and inequalities with absolute value that was presented in different sections in the Third Edition is now combined in a single section in the Fourth Edition.
- In Chapter R, the review chapter, the section that reviews equation solving has been moved to appear now before the sections on rational expressions, radical notation, and rational exponents.
- The material on solving formulas for a specified letter has been moved from Chapter 2 in the Third Edition to Chapter R in the Fourth Edition so that it can be reviewed before it is used to solve a linear equation for one of the variables in Chapter 1.

▶ Emphasis on Functions

Functions are the core of this course and should be presented as a thread that runs throughout the course rather than as an isolated topic. We introduce functions in Chapter 1, whereas many traditional college algebra textbooks cover equation-solving in Chapter 1. Our approach of introducing students to a relatively new concept at the beginning of the course, rather than requiring them to begin with a review of material that was previously covered in intermediate algebra, immediately engages them and serves to help them avoid the temptation not to study early in the course because "I already know this."

The concept of a function can be challenging for students. By repeatedly exposing them to the language, notation, and use of functions, demonstrating visually how functions relate to equations and graphs, and also showing how functions can be used to model real data, we hope to ensure that students not only become comfortable with functions but also come to understand and appreciate them. You will see this emphasis on functions woven throughout the other themes that follow.

■ **Classify the Function Exercises** With a focus on conceptual understanding, students are asked periodically to identify a number of functions by their type (linear, quadratic, rational, and so on). As students progress through the text, the variety of functions with which they are familiar increases and these exercises become more challenging. The "classifying the function" exercises appear with the review exercises in the Skill Maintenance portion of an exercise set. (See pp. 339 and 438.)

▶ Visual Emphasis

Our early introduction of functions allows graphs to be used to provide a visual aspect to solving equations and inequalities. For example, we are able to show students both algebraically and visually that the solutions of a quadratic equation $ax^2 + bx + c = 0$ are the zeros of the quadratic function $f(x) = ax^2 + bx + c$ as well as the first coordinates of the x-intercepts of the graph of that function. This makes it possible for students, particularly visual learners, to gain a quick understanding of these concepts. (See pp. 249, 252, 297, 360, and 425.)

■ **Visualizing the Graph**   Appearing at least once in every chapter, this feature provides students with an opportunity to match an equation with its graph by focusing on the characteristics of the equation and the corresponding attributes of the graph. (See pp. 205, 266, and 356.) In addition to this full-page feature, many of the exercise sets include exercises in which the student is asked to match an equation with its graph or to find an equation of a function from its graph. (See pp. 208, 209, 306, and 408–409.) In MyMathLab, animated Visualizing the Graph features for each chapter allow students to interact with graphs on a whole new level.

■ **Side-by-Side Examples**   Many examples are presented in a side-by-side, two-column format in which the algebraic solution of an equation appears in the left column and a graphical interpretation of the solution appears in the right column. (See pp. 242, 363–364, and 443–444.) This enables students to visualize and comprehend the connections among the solutions of an equation, the zeros of a function, and the x-intercepts of the graph of a function.

■ **Technology Connections**   This feature appears throughout the text to demonstrate how a graphing calculator can be used to solve problems. The technology is set apart from the traditional exposition so that it does not intrude if no technology is desired. Although students might not be using graphing calculators, the graphing calculator windows that appear in the Technology Connection features enhance the visual element of the text, providing graphical interpretations of solutions of equations, zeros of functions, and x-intercepts of graphs of functions. (See pp. 80, 250, and 442.) A graphing calculator manual providing keystroke-level instruction, written by author Judy Penna, is available online. (See Student Supplements.)

▶ Making Connections

■ **Zeros, Solutions, and x-Intercepts**   We find that when students understand the connections among the real zeros of a function, the solutions of its associated equation, and the first coordinates of the x-intercepts of its graph, a door opens to a new level of mathematical comprehension that increases the probability of success in this course. We emphasize zeros, solutions, and x-intercepts throughout the text by using consistent, precise terminology and including exceptional graphics. Seeing this theme repeated in different contexts leads to a better understanding and retention of these concepts. (See pp. 243 and 252.)

■ **Connecting the Concepts**   This feature highlights the importance of connecting concepts. When students are presented with concepts in visual form—using graphs, an outline, or a chart—rather than merely in paragraphs of text, comprehension is streamlined and retention is enhanced. The visual aspect of this feature invites students to stop and check their understanding of how concepts work together in one section or in several sections. This check in turn enhances student performance on homework assignments and exams. (See pp. 132, 252, and 328.)

■ **Annotated Examples**   We have included over 750 Annotated Examples designed to fully prepare the student to work the exercises. Learning is carefully guided with the use of numerous color-coded art pieces and step-by-step annotations. Substitutions and annotations are highlighted in red for emphasis. (See pp. 245 and 433.)

■ **Now Try Exercises**   Now Try Exercises are found after nearly every example. This feature encourages active learning by asking students to do an exercise in the exercise set that is similar to the example the student has just read. (See pp. 243, 347, and 402.)

■ **Synthesis Exercises**   These exercises appear at the end of each exercise set and encourage critical thinking by requiring students to synthesize concepts from several sections or to take a concept a step further than in the general exercises. For the Fourth Edition, these exercises are assignable in MyMathLab. (See pp. 327–328, 412, and 464.)

■ **Real-Data Applications**   We encourage students to see and interpret the mathematics that appears every day in the world around them. Throughout the writing process, we conducted an energetic search for real-data applications, and the result is a variety of examples and exercises that connect the mathematical content with everyday life. Most of these applications feature source lines and many include charts and graphs. Many are drawn from the fields of health, business and economics, life and physical sciences, social science, and areas of general interest such as sports and travel. (See pp. 98, 255, 410 and 461.)

▶ Ongoing Review

The most significant addition to the Fourth Edition is the new ongoing review features that have been integrated throughout to help students reinforce their understanding and improve their success in the course.

New!   ■ **Mid-Chapter Mixed Review**   This new review reinforces understanding of the mathematical concepts and skills covered in the first half of the chapter before students move on to new material in the second half of the chapter. Each review begins with at least three True/False exercises that require students to consider the concepts they have studied and also contains exercises that drill the skills from all prior sections of the chapter. These exercises are assignable in MyMathLab. (See pp. 187–188 and 429–430.)

Collaborative Discussion and Writing Exercises appear in the Mid-Chapter Mixed Review as well. These exercises can be discussed in small groups or by the class as a whole to encourage students to talk about the key mathematical concepts in the chapter. They can also be assigned to individual students to give them an opportunity to write about mathematics. (See pp. 271 and 329.)

A section reference is provided for each exercise in the Mid-Chapter Mixed Review. This tells the student which section to refer to if help is needed to work the exercise. Answers to all exercises in the Mid-Chapter Mixed Review are given at the back of the book.

New!   ■ **Study Guide**   This new feature is found at the beginning of the **Summary and Review** near the end of each chapter. Presented in a two-column format organized by section, this feature gives key concepts and terms in the left column and a worked-out example in the right column. It provides students with a concise and effective review of the chapter that is a solid basis for studying for a test. In MyMathLab, these Study Guides are accompanied by narrated examples to reinforce the key concepts and ideas. (See pp. 285–289 and 465–471.)

■ **Exercise Sets**   There are over 5700 exercises in this text. The exercise sets are enhanced with real-data applications and source lines, detailed art pieces, tables, graphs, and photographs. In addition to the exercises that provide students with concepts presented in the section, the exercise sets feature the following elements to provide ongoing review of topics presented earlier:

   ■ **Skill Maintenance Exercises**. These exercises provide an ongoing review of concepts previously presented in the course, enhancing students' retention of these concepts. These exercises include **Vocabulary Review**, described below, and **Classifying the**

Function exercises, described earlier in the section "Emphasis on Functions." Answers to all Skill Maintenance exercises appear in the answer section at the back of the book, along with a section reference that directs students quickly and efficiently to the appropriate section of the text if they need help with an exercise. (See pp. 209, 280, 359, and 428.)

- **Enhanced Vocabulary Review Exercises.** This feature checks and reviews students' understanding of the vocabulary introduced throughout the text. It appears once in every chapter, in the Skill Maintenance portion of an exercise set, and is intended to provide a continuing review of the terms that students must know in order to be able to communicate effectively in the language of mathematics. (See pp. 219, 284, and 359.) These are now assignable in MyMathLab and can serve as reading quizzes.
- **Enhanced Synthesis Exercises.** These exercises are described under the Making Connections heading and are also assignable in MyMathLab.

■ **Review Exercises**   These exercises in the **Summary and Review** supplement the Study Guide by providing a thorough and comprehensive review of the skills taught in the chapter. A group of true/false exercises appears first, followed by a large number of exercises that drill the skills and concepts taught in the chapter. In addition, three multiple-choice exercises, one of which involves identifying the graph of a function, are included in the Review Exercises for every chapter with the exception of Chapter R, the review chapter. Each Review Exercise is accompanied by a section reference that, as in the Mid-Chapter Mixed Review, directs students to the section in which the material being reviewed can be found. Collaborative Discussion and Writing exercises are also included. These exercises are described under the Mid-Chapter Mixed Review heading on p. xiv. (See pp. 289–292 and 471–474.)

■ **Chapter Test**   The test at the end of each chapter allows students to test themselves and target areas that need further study before taking the in-class test. Each Chapter Test includes a multiple-choice exercise involving identifying the graph of a function (except in Chapter R, in which graphing has not yet been introduced). Answers to all questions in the Chapter Tests appear in the answer section at the back of the book, along with corresponding section references. (See pp. 292–293 and 475–476.)

■ **Review Icons**   Placed next to the concept that a student is currently studying, a review icon references a section of the text in which the student can find and review topics on which the current concept is built. (See pp. 341 and 388.)

■ **Study Tips**   The Study Tips that appear in the text margin provide helpful study hints and promote effective study habits such as good note taking and exam preparation. These tips help students make the connection between study skills and the material being studied. (See pp. 160, 190, and 315.)

▶ Supplements

Graphing Calculator Manual

- By Judith A. Penna
- Contains keystroke-level instruction for the Texas Instruments TI-83 Plus, TI-84 Plus, and TI-89
- Teaches students how to use a graphing calculator using actual examples and exercises from the main text
- Mirrors the topic order in the main text to provide a just-in-time mode of instruction
- Available for download through www. pearsonhighered.com/irc or inside your MyMathLab course

Student's Solutions Manual

ISBN: 0-321-72484-4; 978-0-321-72484-7

- By Judith A. Penna
- Contains completely worked-out solutions with step-by-step annotations for all the odd-numbered exercises in the exercise sets, the Mid-Chapter Mixed Review exercises, and Chapter Review exercises, as well as solutions for all the Chapter Test exercises

Video Resources on DVD-ROM with Optional Subtitles

ISBN: 0-321-72485-2; 978-0-321-72485-4

- Complete set of digitized videos on DVD for student use at home or on campus
- Ideal for distance learning or supplemental instruction
- Features authors Judy Beecher and Judy Penna working through and explaining examples in the text

Annotated Instructor's Edition

ISBN: 0-321-69413-9; 978-0-321-69413-3

- Includes all the answers to the exercise sets, usually right on the page where the exercises appear
- Readily accessible answers help both new and experienced instructors prepare for class efficiently
- Sample homework assignments are now indicated by a blue underline within each end-of-section exercise set and may be assigned in MyMathLab

Instructor's Solutions Manual

ISBN: 0-321-72482-8; 978-0-321-72482-3

- By Judith A. Penna
- Contains worked-out solutions to all exercises in the exercise sets and solutions for all Mid-Chapter Mixed Review exercises, Chapter Review exercises, and Chapter Test exercises

Online Test Bank

- By Laurie Hurley
- Contains four free-response test forms for each chapter following the same format and having the same level of difficulty as the tests in the main text, plus two multiple-choice test forms for each chapter
- Provides six forms of the final examination, four with free-response questions and two with multiple-choice questions
- Available for download through www.pearsonhighered. com/irc or inside your MyMathLab course

TestGen®

- Enables instructors to build, edit, print, and administer tests
- Features a computerized bank of questions developed to cover all text objectives
- Available for download through www.pearsonhighered. com/irc or inside your MyMathLab course

Pearson Adjunct Support Center

- Offers consultation on suggested syllabi, helpful tips for using the textbook support package, assistance with content, and advice on classroom strategies
- Available Sunday through Thursday evenings from 5 P.M. to midnight EST
- e-mail: AdjunctSupport@aw.com; Telephone: 1-800-435-4084; fax: 1-877-262-9774

▶ Media Supplements

MyMathLab® Online Course (Access code required.)

MyMathLab® is a series of text-specific, easily customizable online courses for Pearson Education's textbooks in mathematics and statistics. MyMathLab gives you the tools you need to deliver all or a portion of your course online, whether your students are in a lab or working from home. MyMathLab provides a rich and flexible set of course materials, featuring free-response exercises that are algorithmically generated for unlimited practice and mastery. Students can also use online tools, such as video lectures, animations, and a multimedia textbook, to independently improve their understanding and performance. Instructors can use MyMathLab's homework and test managers to select and assign online exercises correlated directly to the textbook, as well as media related to that textbook, and they can also create and assign their own online exercises and import TestGen® tests for added flexibility. MyMathLab's online gradebook—designed specifically for mathematics and statistics—automatically tracks students' homework and test results and gives you control over how to calculate final grades. You can also add offline (paper-and-pencil) grades to the gradebook.

MyMathLab is now more closely integrated with the text and now offers new question types, for a more robust online experience that mirrors the authors' approach.

- **Example-based videos**, created by the authors themselves, walk students through the detailed solution process for key examples in the textbook. Videos have optional subtitles.
- **Vocabulary exercises** which can serve as reading quizzes have been added.
- **Mid-Chapter Mixed Reviews** are new to the text and are assignable online, helping students to reinforce their understanding of the concepts.
- **Synthesis exercises** are now assignable online, testing students' ability to answer questions that cover multiple concepts.
- **Sample homework assignments** are now indicated by a blue underline within each end-of-section exercise set and may be assigned in MyMathLab.
- **Study Guides** are new to the text. In MyMathLab, these Study Guides are accompanied by narrated examples to reinforce the key concepts and ideas.

MyMathLab also includes access to the **Pearson Tutor Center** (www.pearsontutorservices.com). The Tutor Center is staffed by qualified mathematics instructors who provide textbook-specific tutoring for students via toll-free phone, fax, e-mail, and interactive Web sessions. MyMathLab is available to qualified adopters. For more information, visit our website at www.mymathlab.com or contact your Pearson representative.

MathXL® Online Course (Access code required.)

MathXL® is a powerful online homework, tutorial, and assessment system that accompanies Pearson Education's textbooks in mathematics and statistics. With MathXL, instructors can

- Create, edit, and assign online homework and tests using algorithmically generated exercises correlated at the objective level to the textbook.
- Create and assign their own online exercises and import TestGen tests for added flexibility.
- Maintain records of all student work tracked in MathXL's online gradebook.

With MathXL, students can

- Take chapter tests in MathXL and receive personalized study plans and/or personalized homework assignments based on their test results.
- Use the study plan and/or the homework to link directly to tutorial exercises for the objectives they need to study.
- Access supplemental animations and video clips directly from selected exercises.

MathXL is available to qualified adopters. For more information, visit our website at www. mathxl.com, or contact your Pearson representative.

Videos

The video lectures for this text are available on DVD-ROM, making it easy and convenient for students to watch the videos from a computer either at home or on campus. The videos feature authors Judy Beecher and Judy Penna, who present Example Solutions. Example Solutions walk students through the detailed solution process for the examples in the textbook. The format provides distance-learning students with comprehensive video instruction, but also allows students needing less review to watch instruction on a specific skill or procedure. The videos have optional text subtitles, which can be easily turned on or off for individual student needs. Subtitles are available in English and Spanish.

PowerPoints

PowerPoint Lecture Slides feature presentations written and designed specifically for this text. These lecture slides provide an outline to use in a lecture setting, presenting definitions, figures, and key examples from the text. They are available online within MML or from the Instructor Resource Center at www.pearsonhighered.com/irc.

▶ Acknowledgments

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J. A. B.
J. A. P.
M. L. B.

College Algebra

Visualize Your Success

This textbook is designed to give you the best possible opportunity to learn the concepts and skills taught in it. We realize that your time is valuable, so we communicate in a highly visual way that allows you to focus easily and learn quickly. Take a moment to familiarize yourself with some of the recurring features in this book.

EXAMPLE 3 Solve: $e^{0.08t} = 2500$.

Algebraic Solution

It will make our work easier if we take the natural logarithm when working with equations that have e as a base.

We have

$e^{0.08t} = 2500$

$\ln e^{0.08t} = \ln 2500$ Taking the natural logarithm on both sides

$0.08t = \ln 2500$ Finding the logarithm of a base to a power: $\log_a a^x = x$

$t = \dfrac{\ln 2500}{0.08}$ Dividing by 0.08

$t \approx 97.8$.

The solution is about 97.8.

Visualizing the Solution

The first coordinate of the point of intersection of the graphs of $y = e^{0.08t}$ and $y = 2500$ is about 97.8. This is the solution of the equation.

Graph showing $y = 2500$, $y = e^{0.08t}$, and the point $(97.8, 2500)$.
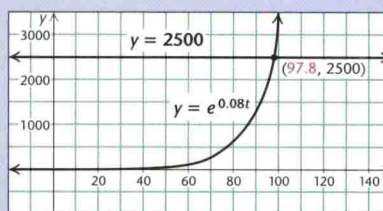
Now Try Exercise 19.

page 442

Algebraic Solution/ Visualizing the Solution side-by-side examples appear throughout the text. They show the algebraic solution of the example along with a graphical representation of the solution, enabling you to see the connection between these two elements.

Now Try exercise suggestions follow nearly every example. They direct you to an exercise that will let you check your understanding of concepts immediately after they are introduced.

5.5   Exercise Set

Solve the exponential equation.

1. $3^x = 81$
2. $2^x = 32$
3. $2^{2x} = 8$
4. $3^{7x} = 27$
5. $2^x = 33$
6. $2^x = 40$
7. $5^{4x-7} = 125$
8. $4^{3x-5} = 16$
9. $27 = 3^{5x} \cdot 9^{x^2}$
10. $3^{x^2+4x} = \frac{1}{27}$
11. $84^x = 70$
12. $28^x = 10^{-3x}$
13. $10^{-x} = 5^{2x}$
14. $15^x = 30$
15. $e^{-c} = 5^{2c}$
16. $e^{4t} = 200$
17. $e^t = 1000$
18. $e^{-t} = 0.04$
19. $e^{-0.03t} = 0.08$
20. $1000e^{0.09t} = 5000$
21. $3^x = 2^{x-1}$
22. $5^{x+2} = 4^{1-x}$

page 448
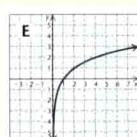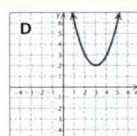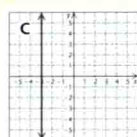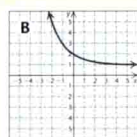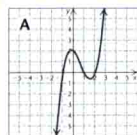
Visualizing the Graph

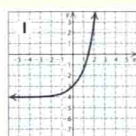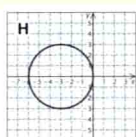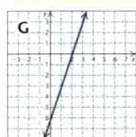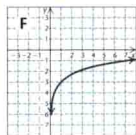Match the equation or function with its graph.

1. $f(x) = 4^x$

2. $f(x) = \ln x - 3$

3. $(x + 3)^2 + y^2 = 9$

4. $f(x) = 2^{-x} + 1$

5. $f(x) = \log_2 x$

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

7. $x = -3$

8. $f(x) = e^x - 4$

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

10. $3x = 6 + y$

Answers on page A-32

A

B

C

D

E

F

G

H

I

J
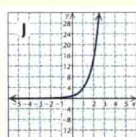
◄ **Visualizing the Graph** exercises will help you develop your ability to make the mental link between different types of equations and their graphs. You will learn to recognize characteristics of equations and their corresponding graphical features.

Connecting the Concepts ► features show how important concepts are related to each other. Rather than using long explanations, this visual format allows you to easily digest and remember the information.

→ CONNECTING THE CONCEPTS

Comparing Exponential Functions and Logarithmic Functions

In the following table, we compare exponential functions and logarithmic functions with bases a greater than 1. Similar statements could be made for a, where $0 < a < 1$. It is helpful to visualize the differences by carefully observing the graphs.

EXPONENTIAL FUNCTION

$y = a^x$
$f(x) = a^x$
$a > 1$
Continuous
One-to-one
Domain: All real numbers, $(-\infty, \infty)$
Range: All positive real numbers, $(0, \infty)$
Increasing
Horizontal asymptote is x-axis:
$(a^x \rightarrow 0$ as $x \rightarrow -\infty)$
y-intercept: $(0, 1)$
There is no x-intercept.
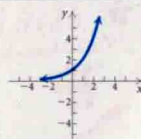
LOGARITHMIC FUNCTION

$x = a^y$
$f^{-1}(x) = \log_a x$
$a > 1$
Continuous
One-to-one
Domain: All positive real numbers, $(0, \infty)$
Range: All real numbers, $(-\infty, \infty)$
Increasing
Vertical asymptote is y-axis:
$(\log_a x \rightarrow -\infty$ as $x \rightarrow 0^+)$
x-intercept: $(1, 0)$
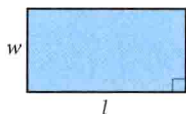There is no y-intercept.

←
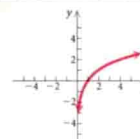
Geometry

Plane Geometry
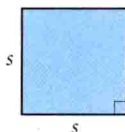
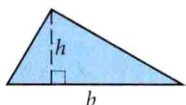**Rectangle**
Area: $A = lw$
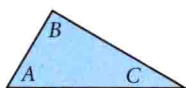Perimeter: $P = 2l + 2w$

Square
Area: $A = s^2$
Perimeter: $P = 4s$

Triangle
Area: $A = \frac{1}{2}bh$
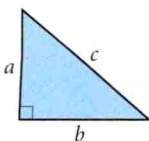
Sum of Angle Measures
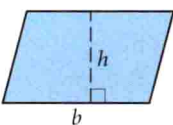$A + B + C = 180°$

Right Triangle
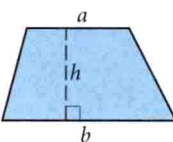Pythagorean theorem
(equation):
$a^2 + b^2 = c^2$

Parallelogram
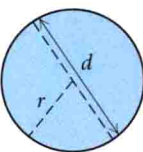Area: $A = bh$

Trapezoid
Area: $A = \frac{1}{2}h(a + b)$
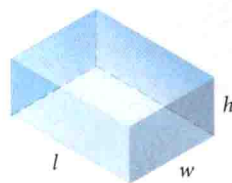
Circle
Area: $A = \pi r^2$
Circumference:
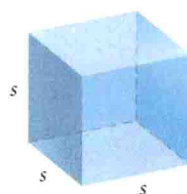$C = \pi d = 2\pi r$

Solid Geometry

Rectangular Solid
Volume: $V = lwh$

Cube
Volume: $V = s^3$

Right Circular Cylinder
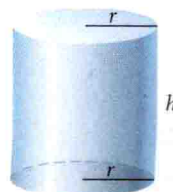Volume: $V = \pi r^2 h$
Lateral surface area:
$L = 2\pi rh$
Total surface area:
$S = 2\pi rh + 2\pi r^2$

Right Circular Cone
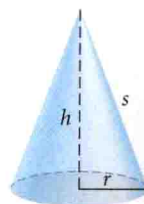Volume: $V = \frac{1}{3}\pi r^2 h$
Lateral surface area:
$L = \pi rs$
Total surface area:
$S = \pi r^2 + \pi rs$
Slant height:
$s = \sqrt{r^2 + h^2}$

Sphere
Volume: $V = \frac{4}{3}\pi r^3$
Surface area: $S = 4\pi r^2$