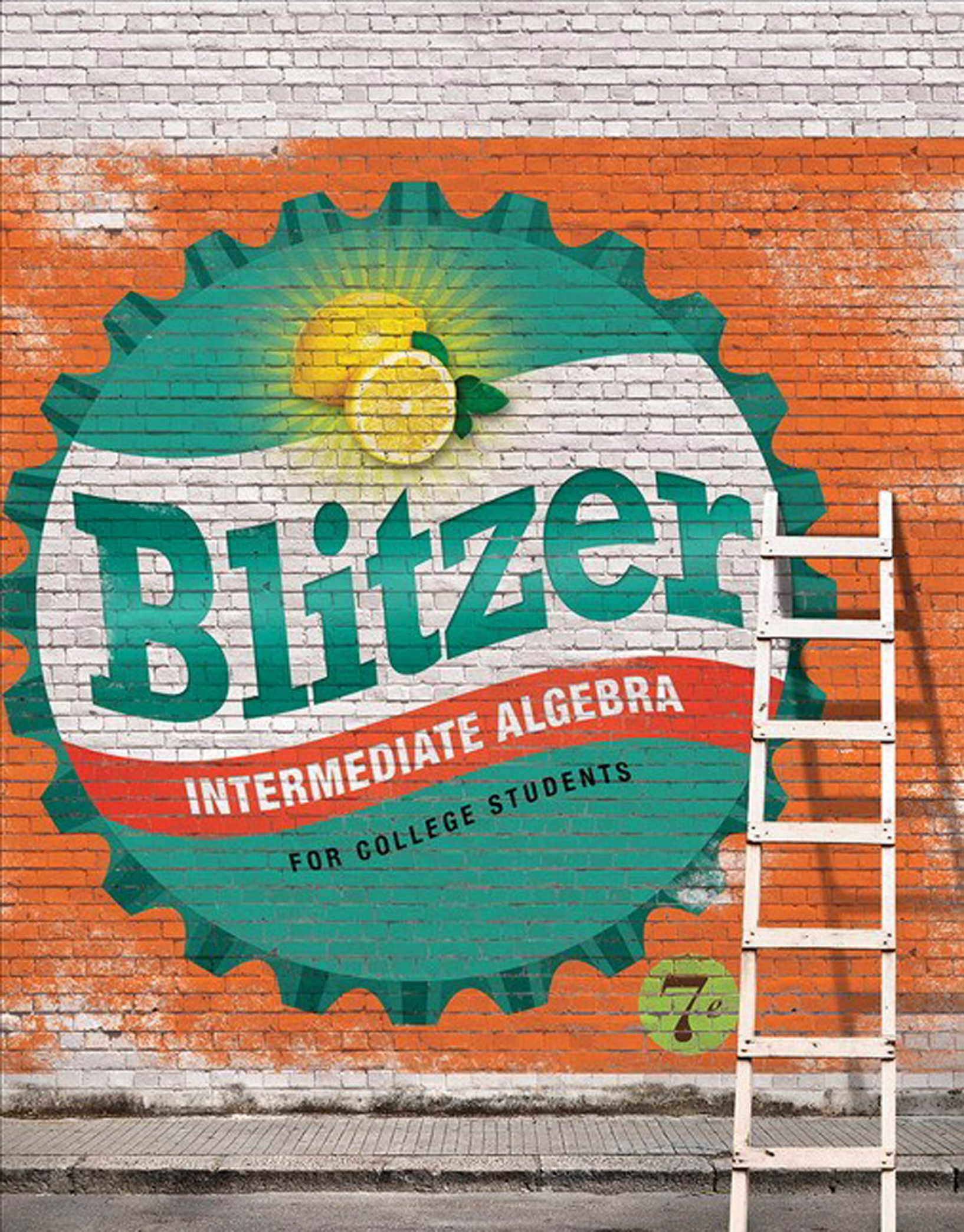

Blitzer
INTERMEDIATE ALGEBRA
FOR COLLEGE STUDENTS
7e

A Brief Guide to **Getting the Most** from This Book

1 Read the Book

Feature	Description	Benefit
Applications Using Real-World Data	From the chapter and section openers through the examples and exercises, interesting applications from nearly every discipline, supported by up-to-date real-world data, are included in every section.	Ever wondered how you'll use algebra? This feature will show you how algebra can solve real problems.
Detailed Worked-Out Examples	Examples are clearly written and provide step-by-step solutions. No steps are omitted, and key steps are thoroughly explained to the right of the mathematics.	The blue annotations will help you to understand the solutions by providing the reason why the algebraic steps are true.
Explanatory Voice Balloons	Voice balloons help to demystify algebra. They translate algebraic language into plain English, clarify problem-solving procedures, and present alternative ways of understanding.	Does math ever look foreign to you? This feature translates math into everyday English.
Great Question!	Answers to students' questions offer suggestions for problem solving, point out common errors to avoid, and provide informal hints and suggestions.	This feature should help you not to feel anxious or threatened when asking questions in class.
Achieving Success	The book's Achieving Success boxes offer strategies for success in learning algebra.	Follow these suggestions to help achieve your full academic potential in mathematics.

2 Work the Problems

Feature	Description	Benefit
Check Point Examples	Each example is followed by a similar problem, called a Check Point, that offers you the opportunity to work a similar exercise. Answers to all Check Points are provided in the answer section.	You learn best by doing. You'll solidify your understanding of worked examples if you try a similar problem right away to be sure you understand what you've just read.
Concept and Vocabulary Checks	These short-answer questions, mainly fill-in-the blank and true/false items, assess your understanding of the definitions and concepts presented in each section.	It is difficult to learn algebra without knowing its special language. These exercises test your understanding of the vocabulary and concepts.
Extensive and Varied Exercise Sets	An abundant collection of exercises is included in an Exercise Set at the end of each section. Exercises are organized within several categories. Practice Exercises follow the same order as the section's worked examples. Practice PLUS Exercises contain more challenging problems that often require you to combine several skills or concepts.	The parallel order of the Practice Exercises lets you refer to the worked examples and use them as models for solving these problems. Practice PLUS provides you with ample opportunity to dig in and develop your problem-solving skills.

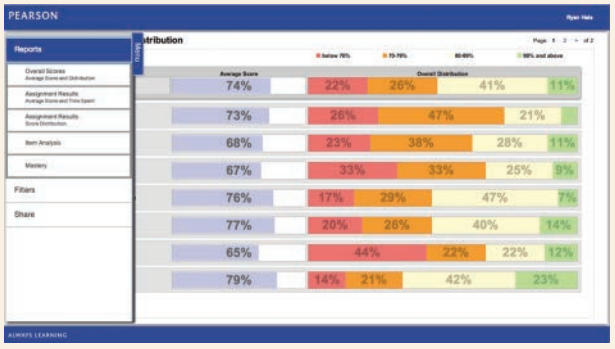
3 Review for Quizzes and Tests

Feature	Description	Benefit
Mid-Chapter Check Points	Near the midway point in the chapter, an integrated set of review exercises allows you to review the skills and concepts you learned separately over several sections.	Combining exercises from the first half of the chapter gives you a comprehensive review before you continue on.
Chapter Review Charts	Each chapter contains a review chart that summarizes the definitions and concepts in every section of the chapter, complete with examples.	Review this chart and you'll know the most important material in the chapter.
Chapter Tests	Each chapter contains a practice test with problems that cover the important concepts in the chapter. Take the test, check your answers, and then watch the Chapter Test Prep Videos.	You can use the Chapter Test to determine whether you have mastered the material covered in the chapter.
Chapter Test Prep Videos	These videos contain worked-out solutions to every exercise in each chapter test.	These videos let you review any exercises you miss on the chapter test.
Lecture Series	These interactive lecture videos highlight key examples from every section of the textbook.	These videos let you review each objective from the textbook that you need extra help on.

BREAKTHROUGH
To improving results

Get the most out of MyMathLab®

MyMathLab, Pearson's online learning management system, creates personalized experiences for students and provides powerful tools for instructors. With a wealth of tested and proven resources, each course can be tailored to fit your specific needs. Talk to your Pearson Representative about ways to integrate MyMathLab into your course for the best results.



Data-Driven Reporting for Instructors

- MyMathLab's comprehensive online gradebook automatically tracks students' results to tests, quizzes, homework, and work in the study plan.
- The Reporting Dashboard, found under More Gradebook Tools, makes it easier than ever to identify topics where students are struggling, or specific students who may need extra help.

Learning in Any Environment

- Because classroom formats and student needs continually change and evolve, MyMathLab has built-in flexibility to accommodate various course designs and formats.
- With a new, streamlined, mobile-friendly design, students and instructors can access courses from most mobile devices to work on exercises and review completed assignments.

Visit www.mymathlab.com and click Get Trained to make sure you're getting the most out of MyMathLab.

SEVENTH EDITION

Intermediate Algebra for College Students

Robert Blitzer
Miami Dade College

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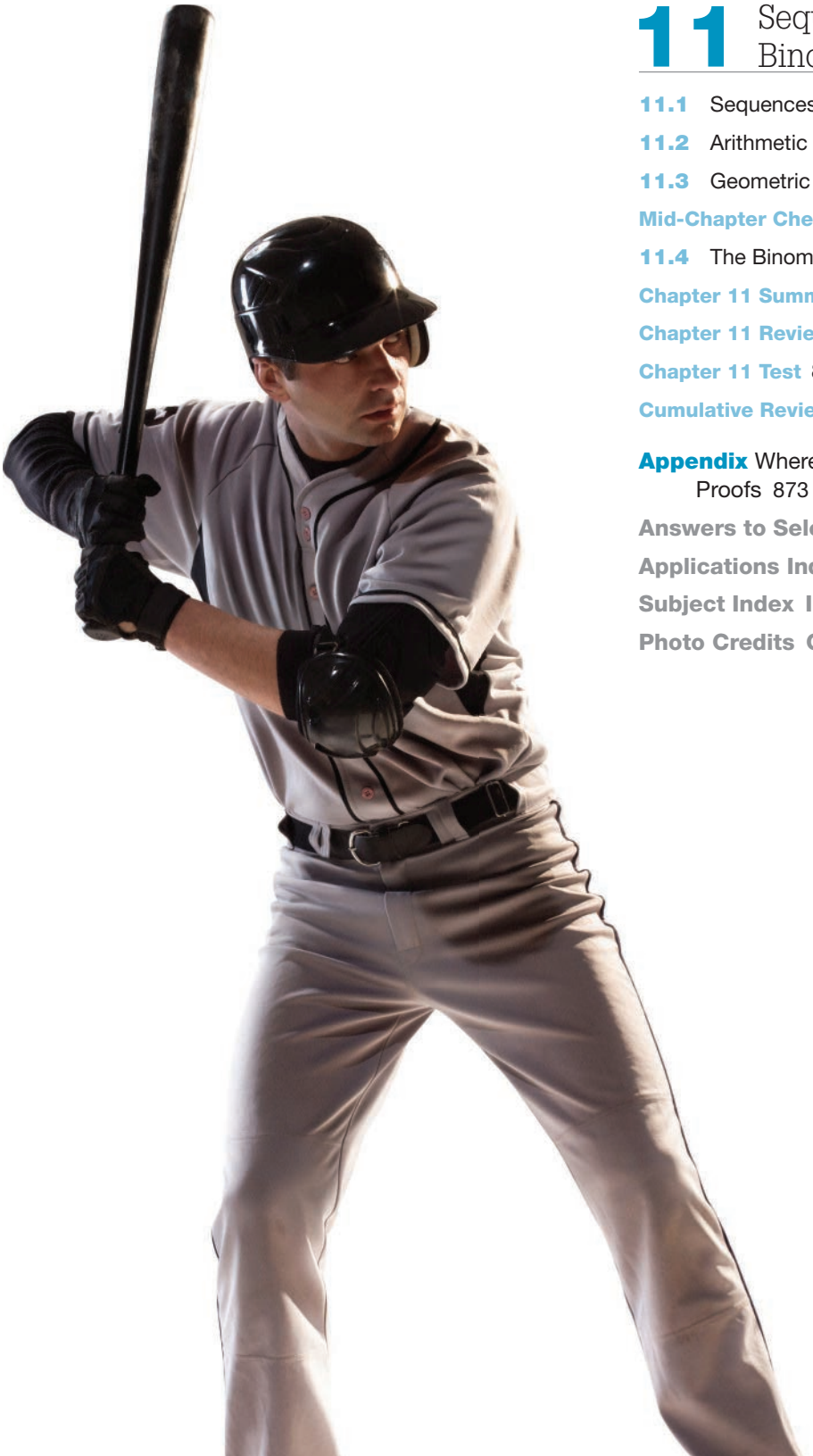

Preface

Intermediate Algebra for College Students, Seventh Edition, provides comprehensive, in-depth coverage of the topics required in a one-term course in intermediate algebra. The book is written for college students who have had a course in introductory algebra or who have demonstrated proficiency in the objectives of such a course. I wrote the book to help diverse students with different backgrounds and career plans succeed in intermediate algebra. *Intermediate Algebra for College Students,* Seventh Edition, has two primary goals:

1. To help students acquire a solid foundation in the skills and concepts of intermediate algebra needed for success in future STEM and non-STEM directed math courses.
2. To show students how algebra can model and solve authentic real-world problems.

One major obstacle in the way of achieving these goals is the fact that very few students actually read their textbook. This has been a regular source of frustration for me and for my colleagues in the classroom. Anecdotal evidence gathered over years highlights two basic reasons students give when asked why they do not take advantage of their textbook:

- "I'll never use this information."
- "I can't follow the explanations."

I've written every page of the Seventh Edition with the intent of eliminating these two objections. The ideas and tools I've used to do so are described in the features that follow. These features and their benefits are highlighted for the student in "A Brief Guide to Getting the Most from This Book," which appears inside the front cover.

What's New in the Seventh Edition?

- **New Applications and Real-World Data.** The Seventh Edition contains 131 new or revised worked-out examples and exercises based on updated and new data sets. Many of these applications involve topics relevant to college students and newsworthy items. Among topics of interest to college students, you'll find new and updated data sets describing student loan debt (Section 1.1, Example 4), tuition costs (Section 1.4, Example 7; Exercise Set 1.4, Exercises 67–68), dormitory charges (Exercise Set 11.2, Exercises 65–66), the number of hours college students study, by major (Exercise Set 3.3, Exercises 39–40), sleep hours of college students (Exercise Set 3.2, Exercise 10), college students and video games (Chapter 6 opener, Section 6.7 opener; Section 6.7, Example 3), and self-assesment of physical health by college freshmen (Chapter 7 Review, Exercise 85). Among newsworthy items, new applications range from the frivolous (Hamachiphobia: correlating those who won't try sushi and those who don't approve of marriage equality: Exercise Set 9.6, Exercise 41)

to the weighty (mentally ill adults in the United States: Chapter 9 Review Exercise 90). Other new and updated applications address climate change (Section 2.4, Example 10 and Check Point 10), the war on drugs and nonviolent inmates in federal prisons (Exercise Set 3.1, Exercise 94; Exercise Set 10.5, Exercise 63), and the changing U.S. population by race/ethnicity (Section 11.2, Example 3).

- **New Blitzer Bonus Videos with Assessment.** The Blitzer Bonus features throughout the textbook have been turned into animated videos that are built into the MyMathLab course. These videos help students make visual connections to algebra and the world around them. Assignable exercises have been created within the MyMathLab course to assess conceptual understanding and mastery. These videos and exercises can be turned into a media assignment within the Blitzer MyMathLab course.
- **Updated Learning Guide.** Organized by the textbook's learning objectives, this updated Learning Guide helps students learn how to make the most of their textbook for test preparation. Projects are now included to give students an opportunity to discover and reinforce the concepts in an active learning environment and are ideal for group work in class.
- **Updated Graphing Calculator Screens.** All screens have been updated using the TI-84 Plus C.

What's New in the Blitzer Developmental Mathematics Series?

Two new textbooks and MyMathLab courses have been added to the series:

- ***Developmental Mathematics*,** First Edition, is intended for a course sequence covering prealgebra, introductory algebra, and intermediate algebra. The text provides a solid foundation in arithmetic and algebra.
- ***Pathways to College Mathematics*,** First Edition, provides a general survey of topics to prepare STEM and non-STEM students for success in a variety of college math courses, including college algebra, statistics, liberal arts mathematics, quantitative reasoning, finite mathematics, and mathematics for education majors. The prerequisite is basic math or prealgebra.
- ***MyMathLab with Integrated Review*** courses are also available for select Blitzer titles. These MyMathLab courses provide the full suite of resources for the core textbook, but also add in study aids and skills check assignments keyed to the prerequisite topics that students need to know, helping them quickly get up to speed.

What Familiar Features Have Been Retained in the Seventh Edition of *Intermediate Algebra for College Students*?

- **Learning Objectives.** Learning objectives, framed in the context of a student question (What am I supposed to learn?), are clearly stated at the beginning of each section. These objectives help students recognize and focus on the section's most important ideas. The objectives are restated in the margin at their point of use.
- **Chapter-Opening and Section-Opening Scenarios.** Every chapter and every section open with a scenario presenting a unique application of mathematics in students' lives outside the classroom. These scenarios are revisited in the course of the chapter or section in an example, discussion, or exercise.
- **Innovative Applications.** A wide variety of interesting applications, supported by up-to-date, real-world data, are included in every section.
- **Detailed Worked-Out Examples.** Each example is titled, making the purpose of the example clear. Examples are clearly written and provide students with detailed step-by-step solutions. No steps are omitted and each step is thoroughly explained to the right of the mathematics.

- **Explanatory Voice Balloons.** Voice balloons are used in a variety of ways to demystify mathematics. They translate algebraic ideas into everyday English, help clarify problem-solving procedures, present alternative ways of understanding concepts, and connect problem solving to concepts students have already learned.
- **Check Point Examples.** Each example is followed by a similar matched problem, called a Check Point, offering students the opportunity to test their understanding of the example by working a similar exercise. The answers to the Check Points are provided in the answer section.
- **Concept and Vocabulary Checks.** This feature offers short-answer exercises, mainly fill-in-the-blank and true/false items, that assess students' understanding of the definitions and concepts presented in each section. The Concept and Vocabulary Checks appear as separate features preceding the Exercise Sets.
- **Extensive and Varied Exercise Sets.** An abundant collection of exercises is included in an Exercise Set at the end of each section. Exercises are organized within eight category types: Practice Exercises, Practice Plus Exercises, Application Exercises, Explaining the Concepts, Critical Thinking Exercises, Technology Exercises, Review Exercises, and Preview Exercises. This format makes it easy to create well-rounded homework assignments. The order of the Practice Exercises is exactly the same as the order of the section's worked examples. This parallel order enables students to refer to the titled examples and their detailed explanations to achieve success working the Practice Exercises.
- **Practice Plus Problems.** This category of exercises contains more challenging practice problems that often require students to combine several skills or concepts. With an average of ten Practice Plus problems per Exercise Set, instructors are provided with the option of creating assignments that take Practice Exercises to a more challenging level.
- **Mid-Chapter Check Points.** At approximately the midway point in each chapter, an integrated set of Review Exercises allows students to review and assimilate the skills and concepts they learned separately over several sections.
- **Graphing and Functions.** Graphing is introduced in Chapter 1 and functions are introduced in Chapter 2, with an integrated graphing functional approach emphasized throughout the book. Graphs and functions that model data appear in nearly every section and Exercise Set. Examples and exercises use graphs of functions to explore relationships between data and to provide ways of visualizing a problem's solution. Because functions are the core of this course, students are repeatedly shown how functions relate to equations and graphs.
- **Integration of Technology Using Graphic and Numerical Approaches to Problems.** Side-by-side features in the technology boxes connect algebraic solutions to graphic and numerical approaches to problems. Although the use of graphing utilities is optional, students can use the explanatory voice balloons to understand different approaches to problems even if they are not using a graphing utility in the course.
- **Great Question!** This feature presents a variety of study tips in the context of students' questions. Answers to questions offer suggestions for problem solving, point out common errors to avoid, and provide informal hints and suggestions. As a secondary benefit, this feature should help students not to feel anxious or threatened when asking questions in class.
- **Achieving Success.** The Achieving Success boxes at the end of many sections offer strategies for persistence and success in college mathematics courses.
- **Chapter Review Grids.** Each chapter contains a review chart that summarizes the definitions and concepts in every section of the chapter. Examples that illustrate these key concepts are also included in the chart.

- **End-of-Chapter Materials.** A comprehensive collection of Review Exercises for each of the chapter's sections follows the review grid. This is followed by a Chapter Test that enables students to test their understanding of the material covered in the chapter. Beginning with Chapter 2, each chapter concludes with a comprehensive collection of mixed Cumulative Review Exercises.
- **Blitzer Bonuses.** These enrichment essays provide historical, interdisciplinary, and otherwise interesting connections to the algebra under study, showing students that math is an interesting and dynamic discipline.
- **Discovery.** Discover for Yourself boxes, found throughout the text, encourage students to further explore algebraic concepts. These explorations are optional and their omission does not interfere with the continuity of the topic under consideration.

I hope that my passion for teaching, as well as my respect for the diversity of students I have taught and learned from over the years, is apparent throughout this new edition. By connecting algebra to the whole spectrum of learning, it is my intent to show students that their world is profoundly mathematical, and indeed, π is in the sky.

Robert Blitzer

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To improving results

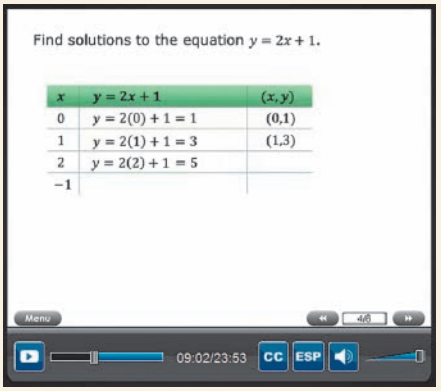
Resources for Success

MyMathLab for the Blitzer Developmental Algebra Series

MyMathLab is available to accompany Pearson's market-leading text offerings. This text's flavor and approach are tightly integrated throughout the accompanying MyMathLab course, giving students a consistent tone, voice, and teaching method that make learning the material as seamless as possible.

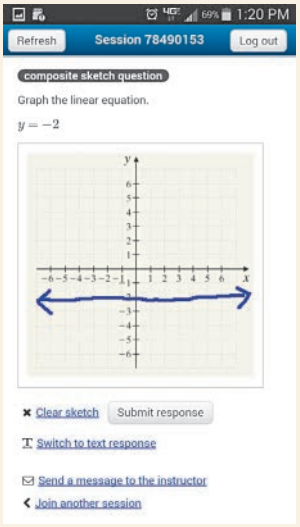
Section Lecture and Chapter Test Prep Videos

An **updated** video program provides a multitude of resources for students. Section Lecture videos walk students through the concepts from every section of the text in a fresh, modern presentation format. Chapter Test Prep videos walk students through the solution of every problem in the text's Chapter Tests, giving students video resources when they might need it most.



Blitzer Bonus Videos

NEW! Animated videos have been created to mirror the Blitzer Bonus features throughout the textbook. Blitzer Bonus features in the text provide interesting real-world connections to the mathematical topics at hand, conveying Bob Blitzer's signature style to engage students. These new Blitzer Bonus videos will help students to connect the topics to the world around them in a visual way. Corresponding assignable exercises in MyMathLab are also available, allowing these new videos to be turned into a media assignment to truly ensure that students have understood what they've watched.



Learning Catalytics

Integrated into MyMathLab, the Learning Catalytics feature uses students' devices in the classroom for an engagement, assessment, and classroom intelligence system that gives instructors real-time feedback on student learning. Learning Catalytics contains Pearson-created content for developmental math topics that allows you to take advantage of this exciting technology immediately.

Student Success Modules

These modules are integrated within the MyMathLab course to help students succeed in college courses and prepare for future professions.

www.mymathlab.com

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To improving results

Resources for Success

Instructor Resources

Annotated Instructor's Edition

This version of the text contains answers to exercises printed on the same page, with graphing answers in a special Graphing Answer Section at the back of the text.

The following resources can be downloaded from www.pearsonhighered.com or in MyMathLab.

PowerPoint® Lecture Slides

Fully editable slides correlated with the textbook include definitions, key concepts, and examples for use in a lecture setting.

Instructor's Solutions Manual

This manual includes fully worked-out solutions to all text exercises.

Instructor's Resource Manual

This manual includes a Mini-Lecture, Skill Builder, and Additional Exercises for every section of the text. It also includes Chapter Test forms, as well as Cumulative and Final Exams, with answers.

TestGen®

TestGen® (www.pearsoned.com/testgen) enables instructors to build, edit, print, and administer tests using a computerized bank of questions developed to cover all the objectives of the text.

Student Resources

The following additional resources are available to support student success:

Learning Guide

UPDATED! Organized by learning objectives, the Learning Guide helps students make the most of their textbook and prepare for tests. Now updated to include projects, students will have the opportunity to discover and reinforce the concepts in an active learning environment. These projects are ideal for group work in class. The Learning Guide is available in MyMathLab, and available as a printed supplement.

Video Lecture Series

Available in MyMathLab, the video program covers every section in the text, providing students with a video tutor at home, in lab, or on the go. The program includes Section Lecture Videos and Chapter Test Prep videos.

Student Solutions Manual

This manual provides detailed, worked-out solutions to odd-numbered section exercises, plus all Check Points, Review/Preview Exercises, Mid-Chapter Check Points, Chapter Reviews, Chapter Tests, and Cumulative Reviews.

Acknowledgments

An enormous benefit of authoring a successful series is the broad-based feedback I receive from the students, dedicated users, and reviewers. Every change to this edition is the result of their thoughtful comments and suggestions. I would like to express my appreciation to all the reviewers, whose collective insights form the backbone of this revision. In particular, I would like to thank the following people for reviewing *Intermediate Algebra for College Students*.

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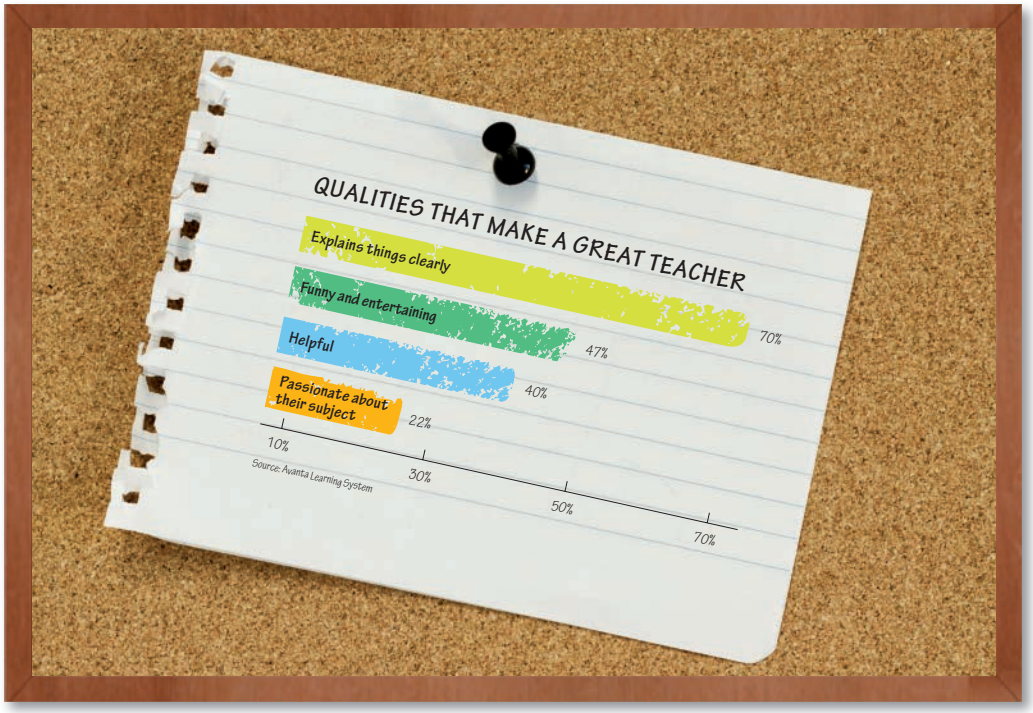
I would like to thank my editors at Pearson, Dawn Giovanniello and Megan Tripp, who guided and coordinated the book from manuscript through production. Thanks to Beth Paquin and Studio Montage for the quirky cover and interior design. Finally, thanks to marketing manager Alicia Frankel for your innovative marketing efforts, and to the entire Pearson sales force, for your confidence and enthusiasm about the book.

To the Student

The bar graph shows some of the qualities that students say make a great teacher.



It was my goal to incorporate each of the qualities that make a great teacher throughout the pages of this book.

Explains Things Clearly

I understand that your primary purpose in reading *Intermediate Algebra for College Students* is to acquire a solid understanding of the required topics in your algebra course. In order to achieve this goal, I've carefully explained each topic. Important definitions and procedures are set off in boxes, and worked-out examples that present solutions in a step-by-step manner appear in every section. Each example is followed by a similar matched problem, called a Check Point, for you to try so that you can actively participate in the learning process as you read the book. (Answers to all Check Points appear in the back of the book.)

Funny/Entertaining

Who says that an algebra textbook can't be entertaining? From our quirky cover to the photos in the chapter and section openers, prepare to expect the unexpected. I hope some of the book's enrichment essays, called Blitzer Bonuses, will put a smile on your face from time to time.

Helpful

I designed the book's features to help you acquire knowledge of intermediate algebra, as well as to show you how algebra can solve authentic problems that apply to your life. These helpful features include:

- ***Explanatory Voice Balloons:*** Voice balloons are used in a variety of ways to make math less intimidating. They translate algebraic language into everyday English, help clarify problem-solving procedures, present alternative ways of understanding concepts, and connect new concepts to concepts you have already learned.
- ***Great Question!:*** The book's Great Question! boxes are based on questions students ask in class. The answers to these questions give suggestions for problem solving, point out common errors to avoid, and provide informal hints and suggestions.
- ***Achieving Success:*** The book's Achieving Success boxes give you helpful strategies for success in learning algebra, as well as suggestions that can be applied for achieving your full academic potential in future college coursework.
- ***Detailed Chapter Review Charts:*** Each chapter contains a review chart that summarizes the definitions and concepts in every section of the chapter. Examples that illustrate these key concepts are also included in the chart. Review these summaries and you'll know the most important material in the chapter!

Passionate about Their Subject

I passionately believe that no other discipline comes close to math in offering a more extensive set of tools for application and development of your mind. I wrote the book in Point Reyes National Seashore, 40 miles north of San Francisco. The park consists of 75,000 acres with miles of pristine surf-washed beaches, forested ridges, and bays bordered by white cliffs. It was my hope to convey the beauty and excitement of mathematics using nature's unspoiled beauty as a source of inspiration and creativity. Enjoy the pages that follow as you empower yourself with the algebra needed to succeed in college, your career, and your life.

Regards,
Bob
Robert Blitzer

About the Author

Bob Blitzer is a native of Manhattan and received a Bachelor of Arts degree with dual majors in mathematics and psychology (minor: English literature) from the City College of New York. His unusual combination of academic interests led him toward a Master of Arts in mathematics from the University of Miami and a doctorate in behavioral sciences from Nova University. Bob's love for teaching mathematics was nourished for nearly 30 years at Miami Dade College, where he received numerous teaching awards, including Innovator of the Year from the League for Innovations in the Community College and an endowed chair based on excellence in the classroom. In addition to *Intermediate Algebra for College Students*, Bob has written textbooks covering developmental mathematics, introductory algebra, college algebra, algebra and trigonometry, precalculus, and liberal arts mathematics, all published by Pearson. When not secluded in his Northern California writer's cabin, Bob can be found hiking the beaches and trails of Point Reyes National Seashore, and tending to the chores required by his beloved entourage of horses, chickens, and irritable roosters.

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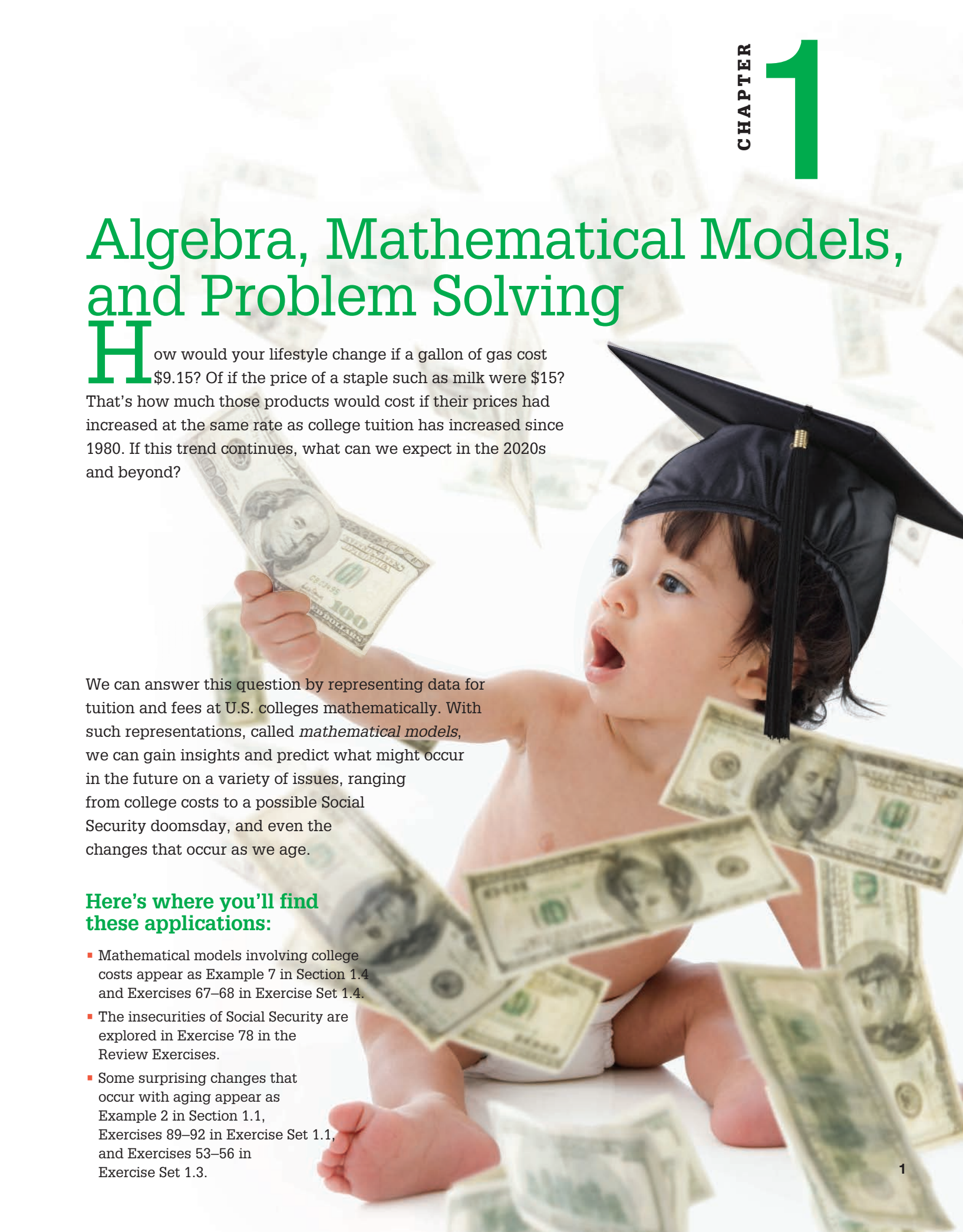
CHAPTER 1

Algebra, Mathematical Models, and Problem Solving

How would your lifestyle change if a gallon of gas cost $9.15? Of if the price of a staple such as milk were $15? That's how much those products would cost if their prices had increased at the same rate as college tuition has increased since 1980. If this trend continues, what can we expect in the 2020s and beyond?



We can answer this question by representing data for tuition and fees at U.S. colleges mathematically. With such representations, called *mathematical models*, we can gain insights and predict what might occur in the future on a variety of issues, ranging from college costs to a possible Social Security doomsday, and even the changes that occur as we age.

Here's where you'll find these applications:

- Mathematical models involving college costs appear as Example 7 in Section 1.4 and Exercises 67–68 in Exercise Set 1.4.
- The insecurities of Social Security are explored in Exercise 78 in the Review Exercises.
- Some surprising changes that occur with aging appear as Example 2 in Section 1.1, Exercises 89–92 in Exercise Set 1.1, and Exercises 53–56 in Exercise Set 1.3.

SECTION

1.1 Algebraic Expressions, Real Numbers, and Interval Notation

What am I supposed to learn?

After studying this section, you should be able to:

1. Translate English phrases into algebraic expressions.
2. Evaluate algebraic expressions.
3. Use mathematical models.
4. Recognize the sets that make up the real numbers.
5. Use set-builder notation.
6. Use the symbols $\in$ and $\notin$.
7. Use inequality symbols.
8. Use interval notation.

As we get older, do we mellow out or become more neurotic? In this section, you will learn how the special language of algebra describes your world, including our improving emotional health with age.

Algebraic Expressions

Algebra uses letters, such as x and y, to represent numbers. If a letter is used to represent various numbers, it is called a **variable**. For example, imagine that you are basking in the sun on the beach. We can let x represent the number of minutes that you can stay in the sun without burning with no sunscreen. With a number 6 sunscreen, exposure time without burning is six times as long, or 6 times x. This can be written $6 \cdot x$, but it is usually expressed as $6x$. Placing a number and a letter next to one another indicates multiplication.

Notice that $6x$ combines the number 6 and the variable x using the operation of multiplication. A combination of variables and numbers using the operations of addition, subtraction, multiplication, or division, as well as powers or roots, is called an **algebraic expression**. Here are some examples of algebraic expressions:

$$x + 6, \quad x - 6, \quad 6x, \quad \frac{x}{6}, \quad 3x + 5, \quad x^2 - 3, \quad \sqrt{x} + 7.$$

Is every letter in algebra a variable? No. Some letters stand for a particular number. Such a letter is called a **constant**. For example, let $d =$ the number of days in a week. The letter d represents just one number, namely 7, and is a constant.

1. Translate English phrases into algebraic expressions.

Translating English Phrases into Algebraic Expressions

Problem solving in algebra involves translating English phrases into algebraic expressions. Here is a list of words and phrases for the four basic operations:

Addition	Subtraction	Multiplication	Division
sum	difference	product	quotient
plus	minus	times	divide
increased by	decreased by	of (used with fractions)	per
more than	less than	twice	ratio

EXAMPLE 1 Translating English Phrases into Algebraic Expressions

Write each English phrase as an algebraic expression. Let x represent the number.

a. Nine less than six times a number

b. The quotient of five and a number, increased by twice the number

Great Question!

Why is it so important to work each of the book's Check Points?

You learn best by doing. Do not simply look at the worked examples and conclude that you know how to solve them. To be sure that you understand the worked examples, try each Check Point. Check your answer in the answer section before continuing your reading. Expect to read this book with pencil and paper handy to work the Check Points.

2 Evaluate algebraic expressions.

Solution

a. Nine less than six times a number: $6x - 9$

b. The quotient of five and a number, increased by twice the number: $\frac{5}{x} + 2x$ ■

CHECK POINT 1 Write each English phrase as an algebraic expression. Let x represent the number.

a. Five more than 8 times a number

b. The quotient of a number and 7, decreased by twice the number

Evaluating Algebraic Expressions

Evaluating an algebraic expression means to find the value of the expression for a given value of the variable.

EXAMPLE 2 Evaluating an Algebraic Expression

We opened the section with a comment about our improving emotional health with age. A test measuring neurotic traits, such as anxiety and hostility, indicates that people may become less neurotic as they get older. **Figure 1.1** shows the average level of neuroticism, on a scale of 0 to 50, for persons at various ages.

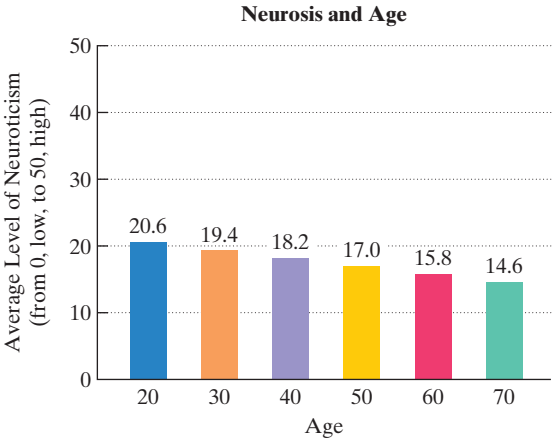


Figure 1.1

Source: L. M. Williams, "The Mellow Years? Neural Basis of Improving Emotional Stability over Age," *The Journal of Neuroscience*, June 14, 2006.

The algebraic expression $23 - 0.12x$ describes the average neurotic level for people who are x years old. Evaluate the expression for $x = 80$. Describe what the answer means in practical terms.

Solution We begin by substituting 80 for x. Because $x = 80$, we will be finding the average neurotic level at age 80.

$$23 - 0.12x$$

Replace x with 80.

$$= 23 - 0.12(80) = 23 - 9.6 = 13.4$$

Thus, at age 80, the average level of neuroticism on a scale of 0 to 50 is 13.4. ■

CHECK POINT 2 Evaluate the expression from Example 2, $23 - 0.12x$, for $x = 10$. Describe what the answer means in practical terms.

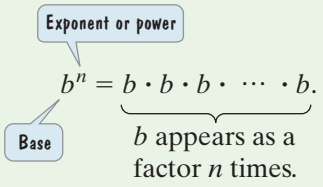
Many algebraic expressions involve *exponents*. For example, the algebraic expression

$$46x^2 + 541x + 17{,}650$$

approximates student-loan debt in the United States, in dollars, x years after 2000. The expression x^2 means $x \cdot x$, and is read "x to the second power" or "x squared." The exponent, 2, indicates that the base, x, appears as a factor two times.

Exponential Notation

If n is a counting number (1, 2, 3, and so on),



b^n is read "the nth power of b" or "b to the nth power." Thus, the nth power of b is defined as the product of n factors of b. The expression b^n is called an **exponential expression**. Furthermore, $b^1 = b$.

Using Technology

You can use a calculator to evaluate exponential expressions. For example, to evaluate 2^4, press the following keys:

Many Scientific Calculators

2 y^x 4 =

Many Graphing Calculators

2 ^ 4 ENTER

Although calculators have special keys to evaluate powers of ten and to square bases, you can always use one of the sequences shown here.

For example,

$$8^2 = 8 \cdot 8 = 64, \quad 5^3 = 5 \cdot 5 \cdot 5 = 125, \quad \text{and} \quad 2^4 = 2 \cdot 2 \cdot 2 \cdot 2 = 16.$$

Many algebraic expressions involve more than one operation. Evaluating an algebraic expression without a calculator involves carefully applying the following order of operations agreement:

The Order of Operations Agreement

1. Perform operations within the innermost parentheses and work outward. If the algebraic expression involves a fraction, treat the numerator and the denominator as if they were each enclosed in parentheses.
2. Evaluate all exponential expressions.
3. Perform multiplications and divisions as they occur, working from left to right.
4. Perform additions and subtractions as they occur, working from left to right.

Great Question!

What am I supposed to do with the worked examples?

Study the step-by-step solutions in the examples. Reading the solutions slowly and with great care will prepare you for success with the Check Points and the exercises in the Exercise Sets.

EXAMPLE 3 Evaluating an Algebraic Expression

Evaluate $7 + 5(x - 4)^3$ for $x = 6$.

Solution

$$\begin{aligned} 7 + 5(x - 4)^3 &= 7 + 5(6 - 4)^3 && \text{Replace } x \text{ with } 6. \\ &= 7 + 5(2)^3 && \text{First work inside parentheses: } 6 - 4 = 2. \\ &= 7 + 5(8) && \text{Evaluate the exponential expression: } 2^3 = 2 \cdot 2 \cdot 2 = 8. \\ &= 7 + 40 && \text{Multiply: } 5(8) = 40. \\ &= 47 && \text{Add. } \blacksquare \end{aligned}$$

CHECK POINT 3 Evaluate $8 + 6(x - 3)^2$ for $x = 13$.

3 Use mathematical models.

Formulas and Mathematical Models

An **equation** is formed when an equal sign is placed between two algebraic expressions. One aim of algebra is to provide a compact, symbolic description of the world. These descriptions involve the use of *formulas*. A **formula** is an equation that uses variables to express a relationship between two or more quantities. Here is an example of a formula:

$$C = \frac{5}{9}(F - 32).$$

Celsius temperature | is | $\frac{5}{9}$ of | the difference between Fahrenheit temperature and 32°.

The process of finding formulas to describe real-world phenomena is called **mathematical modeling**. Such formulas, together with the meaning assigned to the variables, are called **mathematical models**. We often say that these formulas model, or describe, the relationships among the variables.

EXAMPLE 4 Modeling Student-Loan Debt

College students are graduating with the highest debt burden in history. **Figure 1.2** shows the mean, or average, student-loan debt in the United States for five selected graduating years from 2001 through 2013.

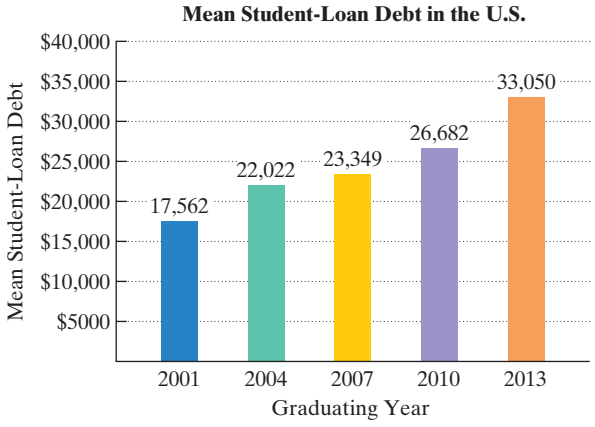


Figure 1.2

Source: Pew Research Center

The formula

$$D = 46x^2 + 541x + 17{,}650$$

models mean student-loan debt, D, in dollars, x years after 2000.

a. Use the formula to find mean student-loan debt for college students who graduated in 2013.

b. Does the mathematical model underestimate or overestimate mean student-loan debt for 2013 shown in **Figure 1.2**? By how much?

Solution

a. Because 2013 is 13 years after 2000, we substitute 13 for x in the given formula. Then we use the order of operations to find D, the mean student-loan debt for the graduating class of 2013.

$D = 46x^2 + 541x + 17{,}650$	This is the given mathematical model.
$D = 46(13)^2 + 541(13) + 17{,}650$	Replace each occurrence of x with 13.
$D = 46(169) + 541(13) + 17{,}650$	Evaluate the exponential expression: $13^2 = 13 \cdot 13 = 169$.
$D = 7774 + 7033 + 17{,}650$	Multiply from left to right: $46(169) = 7774$ and $541(13) = 7033$.
$D = 32{,}457$	Add.

The formula indicates that the mean student-loan debt for college students who graduated in 2013 was $32,457.

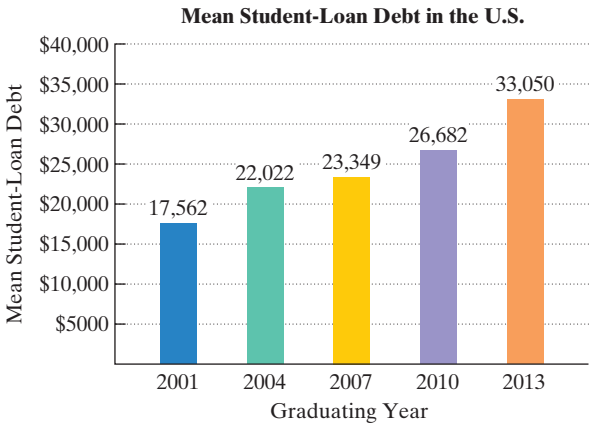


Figure 1.2 (repeated)

b. The mean student-loan debt for 2013 given in **Figure 1.2** is $33,050. The model value, $32,457, is less than the actual data value, $33,050. Thus, the mathematical model underestimates mean student-loan debt for 2013 by

$$\$33{,}050 - \$32{,}457,$$

or by $593. ■

CHECK POINT 4

a. Use the formula in Example 4 to find mean student–loan debt for college students who graduated in 2010.

b. Does the mathematical model underestimate or overestimate mean student-loan debt for 2010 shown in **Figure 1.2**? By how much?

Sometimes a mathematical model gives an estimate that is not a good approximation or is extended to include values of the variable that do not make sense. In these cases, we say that **model breakdown** has occurred. Models that accurately describe data for the past ten years might not serve as reliable predictions for what can reasonably be expected to occur in the future. Model breakdown can occur when formulas are extended too far into the future.

4 Recognize the sets that make up the real numbers.

The Set of Real Numbers

Before we describe the set of real numbers, let's be sure you are familiar with some basic ideas about sets. A **set** is a collection of objects whose contents can be clearly determined. The objects in a set are called the **elements** of the set. For example, the set of numbers used for counting can be represented by

$$\{1, 2, 3, 4, 5, \ldots\}.$$

The braces, { }, indicate that we are representing a set. This form of representation, called the **roster method**, uses commas to separate the elements of the set. The three dots after the 5, called an *ellipsis*, indicate that there is no final element and that the listing goes on forever.

Three common sets of numbers are the *natural numbers*, the *whole numbers*, and the *integers*.

Great Question!

Can I use symbols other than braces to indicate sets in the roster method?

No. Grouping symbols such as parentheses, ( ), and square brackets, [ ], are not used to represent sets in the roster method. Furthermore, only commas are used to separate the elements of a set. Separators such as colons or semicolons are not used.

Natural Numbers, Whole Numbers, and Integers

The Set of Natural Numbers

$$\{1, 2, 3, 4, 5, \ldots\}$$

These are the numbers that we use for counting.

The Set of Whole Numbers

$$\{0, 1, 2, 3, 4, 5, \ldots\}$$

The set of whole numbers includes 0 and the natural numbers.

The Set of Integers

$$\{\ldots, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, \ldots\}$$

The set of integers includes the negatives of the natural numbers and the whole numbers.

5 Use set-builder notation.

A set can also be written in **set-builder notation**. In this notation, the elements of the set are described, but not listed. Here is an example:

$$\{x \mid x \text{ is a natural number less than } 6\}.$$

The set of all x | such that | x is a natural number less than 6.

The same set is written using the roster method as

$$\{1, 2, 3, 4, 5\}.$$

6 Use the symbols $\in$ and $\notin$.

The symbol $\in$ is used to indicate that a number or object is in a particular set. The symbol $\in$ is read "is an element of." Here is an example:

$$7 \in \{1, 2, 3, 4, 5, \ldots\}.$$

7 | is an element of | the set of natural numbers.

The symbol $\notin$ is used to indicate that a number or object is not in a particular set. The symbol $\notin$ is read "is not an element of." Here is an example:

$$\frac{1}{2} \notin \{1, 2, 3, 4, 5, \ldots\}.$$

$\frac{1}{2}$ | is not an element of | the set of natural numbers.

EXAMPLE 5 Using the Symbols $\in$ and $\notin$

Determine whether each statement is true or false:

a. $100 \in \{x \mid x \text{ is an integer}\}$ **b.** $20 \notin \{5, 10, 15\}$.

Solution

a. Because 100 is an integer, the statement

$$100 \in \{x \mid x \text{ is an integer}\}$$

is true. The number 100 is an element of the set of integers.

b. Because 20 is not an element of $\{5, 10, 15\}$, the statement $20 \notin \{5, 10, 15\}$ is true. ■

CHECK POINT 5 Determine whether each statement is true or false:

a. $13 \in \{x \mid x \text{ is an integer}\}$ **b.** $6 \notin \{7, 8, 9, 10\}$.

Another common set is the set of *rational numbers*. Each of these numbers can be expressed as an integer divided by a nonzero integer.

Rational Numbers

The set of **rational numbers** is the set of all numbers that can be expressed as a quotient of two integers, with the denominator not 0.

$$\left\{\frac{a}{b} \,\middle|\, a \text{ and } b \text{ are integers and } b \neq 0\right\}$$

This means that b is not equal to zero.

Three examples of rational numbers are

$$\frac{1}{4} \quad (a = 1,\ b = 4), \qquad \frac{-2}{3} \quad (a = -2,\ b = 3), \qquad \text{and} \qquad 5 = \frac{5}{1} \quad (a = 5,\ b = 1).$$

Can you see that integers are also rational numbers because they can be written in terms of division by 1?

Rational numbers can be expressed in fraction or decimal notation. To express the fraction $\frac{a}{b}$ as a decimal, divide the denominator, b, into the numerator, a. In decimal notation, rational numbers either terminate (stop) or have a digit, or block of digits, that repeats. For example,

$$\frac{3}{8} = 3 \div 8 = 0.375 \quad \text{and} \quad \frac{7}{11} = 7 \div 11 = 0.6363\ldots = 0.\overline{63}.$$

The decimal stops: it is a terminating decimal.

This is a repeating decimal. The bar is written over the repeating part.

Some numbers cannot be expressed as terminating or repeating decimals. An example of such a number is $\sqrt{2}$, the square root of 2. The number $\sqrt{2}$ is a number that can be squared to give 2. No terminating or repeating decimal can be squared to get 2. However, some approximations have squares that come close to 2. We use the symbol $\approx$, which means "is approximately equal to."

- $\sqrt{2} \approx 1.4$ because $(1.4)^2 = (1.4)(1.4) = 1.96$.
- $\sqrt{2} \approx 1.41$ because $(1.41)^2 = (1.41)(1.41) = 1.9881$.
- $\sqrt{2} \approx 1.4142$ because $(1.4142)^2 = (1.4142)(1.4142) = 1.99996164$.

$\sqrt{2}$ is an example of an *irrational number*.

Irrational Numbers

The set of **irrational numbers** is the set of numbers whose decimal representations neither terminate nor repeat. Irrational numbers cannot be expressed as quotients of integers.

Examples of irrational numbers include

$$\sqrt{3} \approx 1.73205 \quad \text{and} \quad \pi(\text{pi}) \approx 3.141593.$$

Not all square roots are irrational. For example, $\sqrt{25} = 5$ because $5^2 = 5 \cdot 5 = 25$. Thus, $\sqrt{25}$ is a natural number, a whole number, an integer, and a rational number $\left(\sqrt{25} = \frac{5}{1}\right)$.

The set of *real numbers* is formed by combining the sets of rational numbers and irrational numbers. Thus, every real number is either rational or irrational, as shown in **Figure 1.3**.

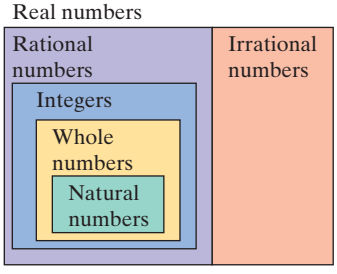


Figure 1.3 Every real number is either rational or irrational.

Real Numbers

The set of **real numbers** is the set of numbers that are either rational or irrational:

$$\{x \mid x \text{ is rational or } x \text{ is irrational}\}.$$

The Real Number Line

The **real number line** is a graph used to represent the set of real numbers. An arbitrary point, called the **origin**, is labeled 0. Select a point to the right of 0 and label it 1. The distance from 0 to 1 is called the **unit distance**. Numbers to the right of the origin are **positive** and numbers to the left of the origin are **negative**. The real number line is shown in **Figure 1.4**.

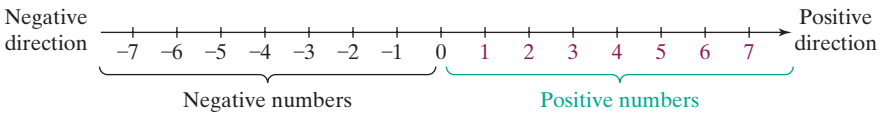
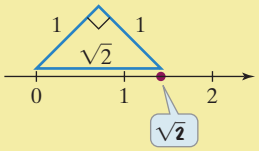


Figure 1.4 The real number line

Great Question!

How did you locate $\sqrt{2}$ as a precise point on the number line in Figure 1.5?

We used a right triangle with two legs of length 1. The remaining side has a length measuring $\sqrt{2}$.



We'll have lots more to say about right triangles later in the book.

7 Use inequality symbols.

Real numbers are **graphed** on a number line by placing a dot at the correct location for each number. The integers are easiest to locate. In **Figure 1.5**, we've graphed six rational numbers and three irrational numbers on a real number line.

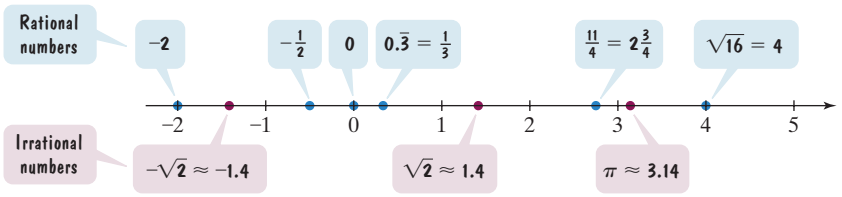


Figure 1.5 Graphing numbers on a real number line

Every real number corresponds to a point on the number line and every point on the number line corresponds to a real number. We say that there is a **one-to-one correspondence** between all the real numbers and all points on a real number line.

Ordering the Real Numbers

On the real number line, the real numbers increase from left to right. The lesser of two real numbers is the one farther to the left on a number line. The greater of two real numbers is the one farther to the right on a number line.

Look at the number line in **Figure 1.6**. The integers -4 and -1 are graphed.

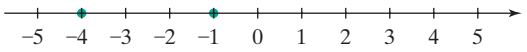


Figure 1.6

Observe that -4 is to the left of -1 on the number line. This means that -4 is less than -1.

$$-4 < -1$$

-4 is less than -1 because -4 is to the left of -1 on the number line.

In **Figure 1.6**, we can also observe that -1 is to the right of -4 on the number line. This means that -1 is greater than -4.

$$-1 > -4$$

-1 is greater than -4 because -1 is to the right of -4 on the number line.

The symbols $<$ and $>$ are called **inequality symbols**. These symbols always point to the lesser of the two real numbers when the inequality statement is true.

-4 is less than -1. $-4 < -1$ The symbol points to -4, the lesser number.

-1 is greater than -4. $-1 > -4$ The symbol still points to -4, the lesser number.

The symbols $<$ and $>$ may be combined with an equal sign, as shown in the following table:

Symbol	Meaning	Examples	Explanation
$a \le b$	a is less than or equal to b.	$2 \le 9$ $9 \le 9$	Because $2 < 9$ Because $9 = 9$
$b \ge a$	b is greater than or equal to a.	$9 \ge 2$ $2 \ge 2$	Because $9 > 2$ Because $2 = 2$

This inequality is true if either the $<$ part or the $=$ part is true.

This inequality is true if either the $>$ part or the $=$ part is true.

EXAMPLE 6 Using Inequality Symbols

Write out the meaning of each inequality. Then determine whether the inequality is true or false.

a. $-5 < -1$ **b.** $6 > -2$ **c.** $-6 \le 3$ **d.** $10 \ge 10$ **e.** $-9 \ge 6$