Julie Miller

Donna Gerken

College Algebra

Second Edition

Mc Graw Hill Education

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Julie Miller
Daytona State College

Digital contributions from
Donna Gerken
Miami-Dade College Kendall

Mc Graw Hill Education

COLLEGE ALGEBRA, SECOND EDITION

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About the Authors

Julie Miller is from Daytona State College where she has taught developmental and upper-level mathematics courses for 20 years. Prior to her work at DSC, she worked as a software engineer for General Electric in the area of flight and radar simulation. Julie earned a bachelor of science in applied mathematics from Union College in Schenectady, New York, and a master of science in mathematics from the University of Florida. In addition to this textbook, she has authored textbooks in developmental mathematics, trigonometry, and precalculus, as well as several short works of fiction and nonfiction for young readers.

"My father is a medical researcher, and I got hooked on math and science when I was young and would visit his laboratory. I remember doing simple calculations with him and using graph paper to plot data points for his experiments. He would then tell me what the peaks and features in the graph meant in the context of his experiment. I think that applications and hands-on experience made math come alive for me, and I'd like to see math come alive for my students."

Donna Gerken is a professor at Miami Dade College where she has taught developmental courses, honors classes, and upper-level mathematics classes for decades. Throughout her career she has been actively involved with many projects at Miami Dade including those on computer learning, curriculum design, and the use of technology in the classroom. Donna's bachelor of science in mathematics and master of science in mathematics are both from the University of Miami.

Letter from the Authors

For many students, college algebra serves as a gateway course to the higher levels of mathematics needed for a variety of careers. Our goal is to offer every student an opportunity for success in college algebra by bringing together a seamless integration of print and digital content delivery. The clear, concise writing style and pedagogical features of our textbook continue throughout the online content in ConnectMath, in our instructional videos, and in the adaptive reading and learning experience of SmartBook.

The main objectives of this college algebra textbook and our digital content are threefold:

- To provide students with a clear and logical presentation of fundamental concepts that will prepare them for continued study in mathematics.
- To help students develop logical thinking and problem-solving skills that will benefit them in all aspects of life.
- To motivate students by demonstrating the significance of mathematics in their lives through practical applications.

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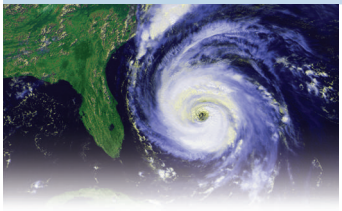
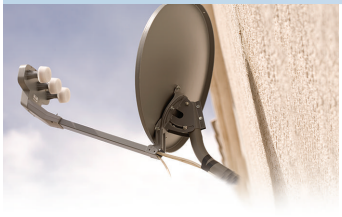
Dedications

To my parents Kent and Joanne Miller who have always taught me the value of education. —Julie Miller

For all the students who keep apologizing for asking too many questions. Keep doing that, and I'll keep listening. —Donna Gerken

Table of Contents





Key Features

Clear, Precise Writing

Because a diverse group of students take this course, Julie Miller has written this manuscript to use simple and accessible language. Through her friendly and engaging writing style, students are able to understand the material easily.

Exercise Sets

The exercises at the end of each section are graded, varied, and carefully organized to maximize student learning:

- **Prerequisite Review Exercises** begin the section-level exercises and ensure that students have the foundational skills to complete the homework sets successfully.
- **Concept Connections** prompt students to review the vocabulary and key concepts presented in the section.
- **Core Exercises** are presented next and are grouped by objective. These exercises are linked to examples in the text and direct students to similar problems whose solutions have been stepped-out in detail.
- **Mixed Exercises** do *not* refer to specific examples so that students can dip into their mathematical toolkit and decide on the best technique to use.
- **Write About It** exercises are designed to emphasize mathematical language by asking students to explain important concepts.
- **Technology Connections** require the use of a graphing utility and are found at the end of exercise sets. They can be easily skipped for those who do not encourage the use of calculators.
- **Expanding Your Skills Exercises** challenge and broaden students' understanding of the material.

Problem Recognition Exercises

Problem Recognition Exercises appear in strategic locations in each chapter of the text. These exercises provide students with an opportunity to synthesize multiple concepts and decide which problem-solving technique to apply to a given problem.

Examples

- The examples in the textbook are stepped-out in detail with thorough annotations at the right explaining each step.
- Following each example is a similar **Skill Practice** exercise to engage students by practicing what they have just learned.
- For the instructor, references to an even-numbered exercise are provided next to each example. These exercises are highlighted with blue circles in the exercise sets and mirror the related examples. With increased demands on faculty time, this has been a popular feature that helps faculty write their lectures and develop their presentation of material. If an instructor presents all of the highlighted exercises, then each objective of that section of text will be covered.

Modeling and Applications

One of the most important tools to motivate our students is to make the mathematics they learn meaningful in their lives. The textbook is filled with robust applications and numerous opportunities for mathematical modeling for those instructors looking to incorporate these features into their course.

Callouts

Throughout the text, popular tools are included to highlight important ideas. These consist of:

- **Tip** boxes that offer additional insight to a concept or procedure.
- **Avoiding Mistakes** boxes that fend off common mistakes.
- **Point of Interest** boxes that offer interesting and historical mathematical facts.
- **Instructor Notes** to assist with lecture preparation.

Graphing Calculator Coverage

Material is presented throughout the book illustrating how a graphing utility can be used to view a concept in a graphical manner. The goal of the calculator material is not to replace algebraic analysis, but rather, to enhance understanding with a visual approach. Graphing calculator examples are placed in self-contained boxes and may be skipped by instructors who choose not to implement the calculator. Similarly, the graphing calculator exercises are found at the end of the exercise sets and may also be easily skipped.

End-of-Chapter Materials

The textbook has the following end-of-chapter materials for students to review before test time:

- Brief summary with references to key concepts. A detailed summary is located at www.mhhe.com/millercollegealgebra.
- Chapter review exercises.
- Chapter test.
- Cumulative review exercises. These exercises cover concepts in the current chapter as well as all preceding chapters.

Updates to College Algebra:

- Two new sections, "Algebra for Calculus" and "Equations and Inequalities for Calculus", were added to Chapter R and Chapter 1. These additions provide STEM students an opportunity to connect current topics to what they'll learn in calculus.
- New "Prerequisite Review" exercises appear in every section. These allow students to ensure they have the necessary foundational skills to be successful in the section.
- Over 600 algorithmic homework exercises were added to Connect Math Hosted by ALEKS to ensure 90% textbook coverage.
- SmartBook content has been revised and enriched. For the first time, SmartBook is now available within Connect Math Hosted by ALEKS.
- 1200 new questions were added to the TestGen testbank.
- Graphing calculator screenshots have been updated to reflect the TI-84 Plus C.
- Section 2.7 for investigating increasing, decreasing, and constant behavior of a function now presents open intervals. This has also been updated in all of the digital materials accompanying the text.
- Sections R.1, R.2, 1.7 & 1.8 have been streamlined to provide greater clarity.
- New applications appear in Chapter 7 to provide students more real-world context for conic sections.
- Applications and real-world data have been updated, where appropriate, to ensure that content remains relevant and current.
- Wolfram Alpha Activities have been added to the Instructor's Resource Manual to allow students to explore college algebra in greater depth.

Supplement Package

Supplements for the Instructor

Author-Created Digital Media

Digital assets were created exclusively by the author team to ensure that the author voice is present and consistent throughout the supplement package.

- The coauthor, Donna Gerken, ensures that each algorithm in the online homework has a stepped-out solution that matches the textbook's writing style.
- Julie Miller created **video content** (lecture videos, exercise videos, graphing calculator videos, and Excel videos) to give students access to classroom-like instruction by the author.
- Julie Miller constructed over 50 **dynamic math animations** to accompany the college algebra text. The animations are diverse in scope and give students an interactive approach to conceptual learning. The animated content illustrates difficult concepts by leveraging the use of on-screen movement where static images in the text may fall short. They are organized in Connect hosted by ALEKS by chapter and section.

The *Instructor's Resource Manual* (IRM) is a printable electronic supplement put together by the author team. The IRM includes Guided Lecture Notes, Classroom Activities using Wolfram Alpha, and Group Activities.

- The Guided Lecture Notes are keyed to the objectives in each section of the text. The notes step through the material with a series of questions and exercises that can be used in conjunction with lecture.
- The Classroom Activities using Wolfram Alpha promote active learning in the classroom by using a powerful online resource.
- A Group Activity is available for each chapter of the book to promote classroom discussion and collaboration.

The *Instructor's Solution Manual* provides comprehensive, worked-out solutions to all exercises in the section exercises, review exercises, problem recognition exercises, chapter tests, and cumulative reviews. The steps shown in the solutions match the style and methodology of solved examples in the textbook.

TestGen is a computerized test bank utilizing algorithm-based testing software to create customized exams quickly. This user-friendly program enables instructors to search for questions by topic, format, or difficulty level; to edit existing questions, or to add new ones; and to scramble questions and answer keys for multiple versions of a single test. Hundreds of text-specific, open-ended, and multiple-choice questions are included in the question bank.

Annotated Instructor's Edition

- Answers to exercises appear adjacent to each exercise set, in a color used only for annotations.
- Instructors will find helpful notes within the margins to consider while teaching.
- References to even-numbered exercises appear in the margin next to each example for the instructor to use as Classroom Examples.

Power Points present key concepts and definitions with fully editable slides that follow the textbook. An instructor may project the slides in class or post to a website in an online course.

Supplements for the Student

Student Worksheets including guided lecture notes that step through the key objectives and Problem Recognition Exercise worksheets.

ALEKS® Prep for College Algebra

ALEKS Prep for College Algebra focuses on prerequisites and introductory material for College Algebra. These prep products can be used during the first 3 weeks of a course to prepare students for future success in the course and to increase retention and pass rates.

Connect Math® Hosted by ALEKS

Connect Math Hosted by ALEKS Corp. is an exciting, new assignment and assessment ehomework platform. Starting with an easily viewable, intuitive interface, students will be able to access key information, complete homework assignments, and utilize an integrated, media-rich eBook.

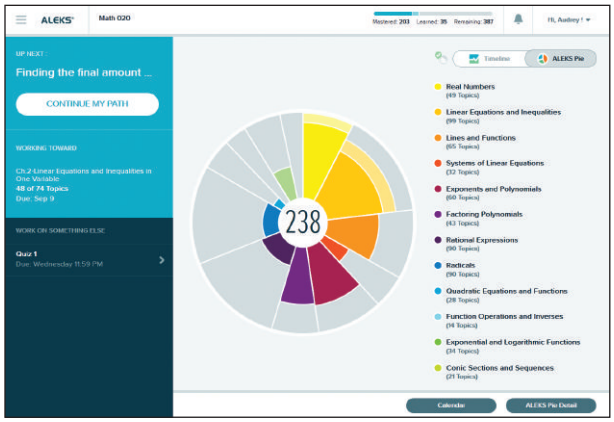
Smartbook® is the first and only adaptive reading experience available for the higher education market. Powered by the intelligent and adaptive LearnSmart engine, SmartBook facilitates the reading process by identifying what content a student knows and doesn't know. As a student reads, the material continously adapts to ensure the student is focused on the content he or she needs the most to close specific knowledge gaps.

Detailed Chapter Summaries are available at www.mhhe.com/millercollegealgebra.

Efficient. Easy to Use. Effective. Engaging.
Gives Your Students the ALEKS Advantage

Are your students prepared for your course? Do they learn at different paces? Is there inconsistency between homework and test scores? ALEKS successfully addresses these core challenges and more.

With decades of scientific research behind its creation, ALEKS offers the most advanced adaptive learning technology that is proven to increase student success in math.



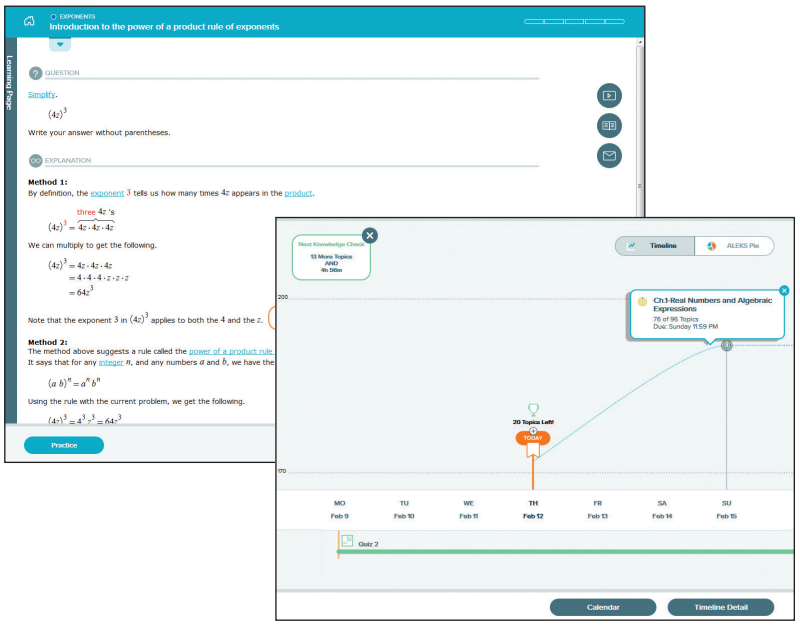
Optimized, Structured Learning

Using adaptive artificial intelligence, ALEKS identifies precisely what each student knows and doesn't know, and prescribes an individualized learning plan tailored to their unique strengths and weaknesses:

- Targets critical knowledge gaps
- Open-response environment
- Motivates student learning
- Presents only topics students are ready to learn
- Enhances learning with interactive resources
- Provides a structured learning path

Student-Friendly Learning Experience

ALEKS is designed to meet the needs of today's students. A clean, modern, mobile-ready interface allows students to easily navigate their learning, track their progress and manage their assignments from anywhere.



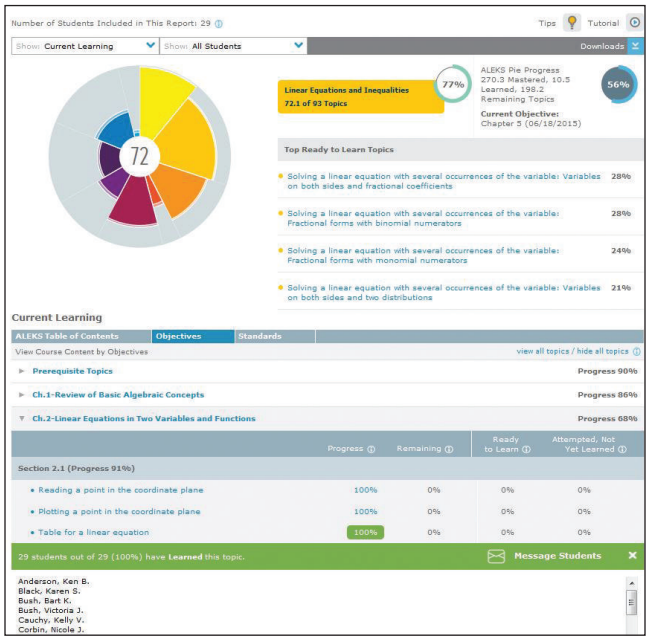
> "I evaluated many different options, and ALEKS provided, by far, the best cycle of assessment and learning that allows for individualized instructional paths . . . no other program matches ALEKS."
>
> —**Professor Eliza Gallagher,** ***Clemson University, SC***

Learn More: **Successinmath.com**

THE ALEKS Instructor Module includes intuitive customization and management features that help save you valuable time and effort. Easily manage your courses and track student progress, all through one simple interface.

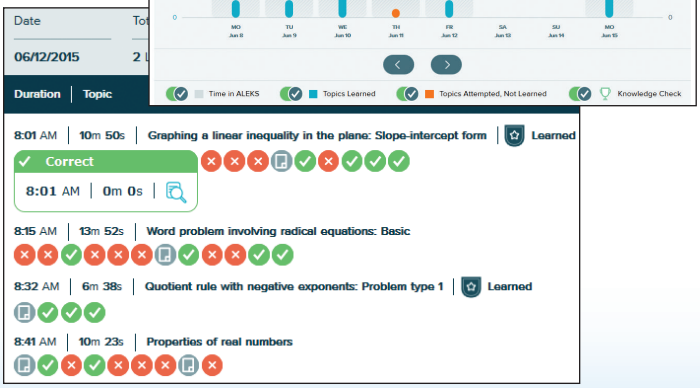
- Create learning goals with due dates that align with your textbook/syllabi and to pace student learning
- Implementation services and training help make setup simple and timely
- 100% mobile-ready allows you to manage your classes from anywhere
- LMS integration offers single sign-on and gradebook sync capabilities

ALEKS Reporting provides detailed data on student progress, allowing you to quickly identify intervention needs and to better understand student learning behaviors. View data for individual students up to the multi-campus level.



View student progress in a course area or at the individual topic level, including which topics students are struggling with the most.

Use this data to inform your teaching, group students based on similar knowledge levels, and shape a meaningful learning experience for your students.



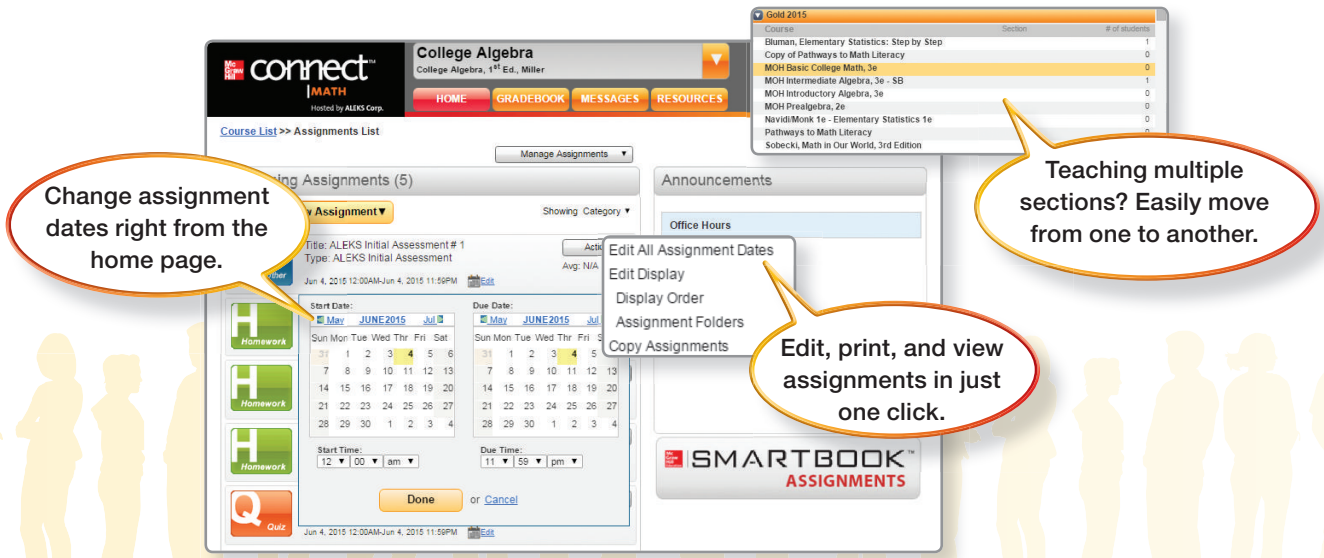
View a daily breakdown of how students learn in ALEKS, including the exact problems they attempt and their answers. This will help you to identify common mistakes and understand their behavior pattern, such as when they study and how frequently.

Learn More: **Successinmath.com**

Connect Math Hosted by ALEKS

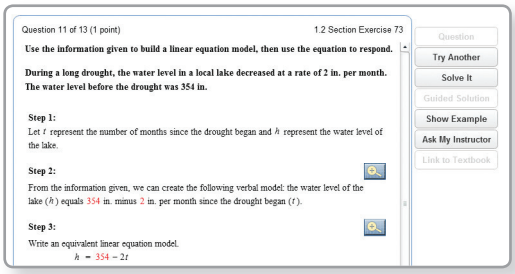
Built By Today's Educators, For Today's Students

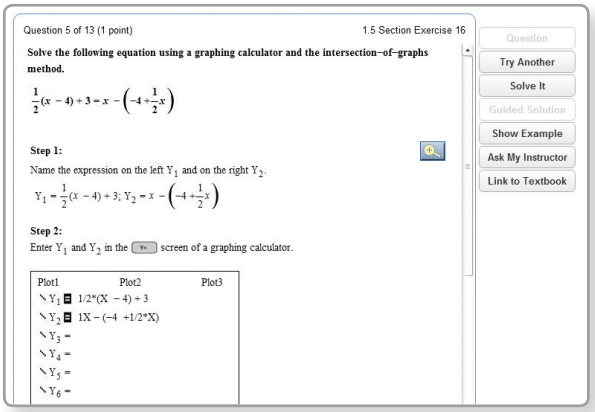
Fewer clicks means more time for you…



…and your students.

Online Exercises were carefully selected and developed to provide a seamless transition from textbook to technology.





For consistency, the guided solutions match the style and voice of the original text as though the author is guiding the students through the problems.

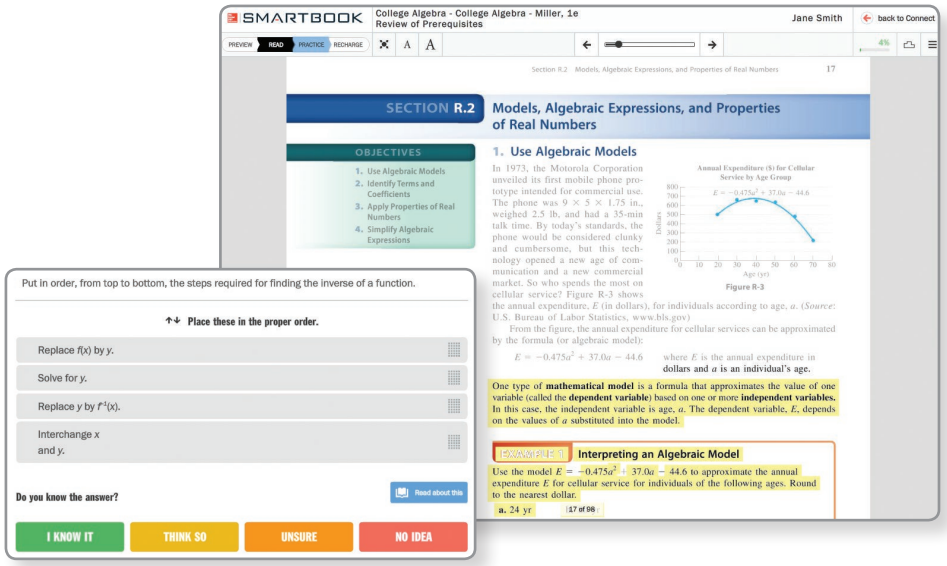
Quality Content For Today's Online Learners

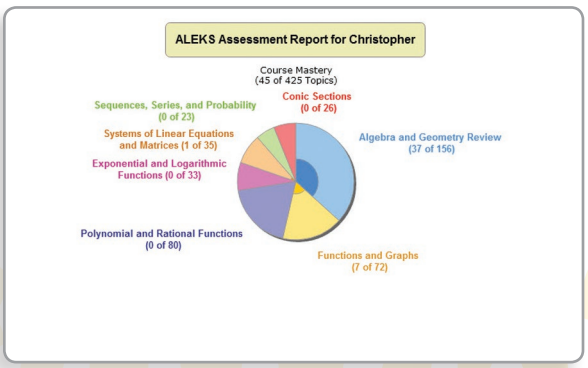
Why SmartBook? Because it's more than just words on a page.

SMARTBOOK™ Students today thrive on efficiency, mobility, and motivation. And SmartBook delivers. SmartBook is the first adaptive reading experience designed to change the way students learn. Students and instructors can enjoy access to SmartBook anywhere, anytime (now available offline) with a new and improved mobile interface. If students still prefer holding a text as they study, they can **order a loose-leaf copy of their textbook for a significant discount.**

SmartBook breaks down the learning experience into four stages: *Preview, Read, Practice,* and *Recharge*. Each stage provides personalized guidance and just-in-time remediation to ensure students stay focused and learn as efficiently as possible. With LearnSmart technology, questions are designed to foster critical thinking and conceptual learning.

Reports are also available to both students and instructors that track progress and show each student's strengths and weaknesses. What does this mean for you? Teach a more informed classroom and provide more personalized guidance.





The ALEKS® Initial Assessment is an artificially intelligent (AI), diagnostic assessment that identifies precisely what a student knows. Instructors can then use this information to make more informed decisions on what topics to cover in more detail with the class.

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Our Commitment to Market Development and Accuracy

Acknowledgments:

Paramount to the development of *College Algebra* was the invaluable feedback provided by the instructors from around the country who reviewed the manuscript or attended a market development event over the course of the several years the text was in development.

A Special Thanks to All of the Event Attendees Who Helped Shape *College Algebra*.

Focus groups and symposia were conducted with instructors from around the country to provide feedback to editors and the authors and ensure the direction of the text was meeting the needs of students and instructors.

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R

Review of Prerequisites

Chapter Outline

Athletes know that in order to optimize their performance they need to pace themselves and be mindful of their target heart rate. For example, a 25-year-old with a maximum heart rate of 195 beats per minute should strive for a target heart rate zone of between 98 and 166 beats per minute. This correlates to between 50% and 85% of the individual's maximum heart rate (Source: American Heart Association, www.americanheart.org). The mathematics involved in finding maximum heart rate and an individual's target heart rate zone use a linear model relating age and resting heart rate. An introduction to modeling is presented here in Chapter R along with the standard order of operations used to carry out these calculations.

Chapter R reviews skills and concepts required for success in college algebra. Just as an athlete must first learn the basics of a sport and build endurance and speed, a student studying mathematics must focus on necessary basic skills to prepare for the challenge ahead. Preparation for algebra is comparable to an athlete preparing for a sporting event. Putting the time and effort into the basics here in Chapter R will be your foundation for success in later chapters.

SECTION R.1 Sets and the Real Number Line

OBJECTIVES

1. Identify Subsets of the Set of Real Numbers
2. Use Inequality Symbols and Interval Notation
3. Find the Union and Intersection of Sets
4. Evaluate Absolute Value Expressions
5. Use Absolute Value to Represent Distance
6. Apply the Order of Operations
7. Simplify Algebraic Expressions
8. Write Algebraic Models

1. Identify Subsets of the Set of Real Numbers

A hybrid vehicle gets 48 mpg in city driving and 52 mpg on the highway. The formula $A = \frac{1}{48}c + \frac{1}{52}h$ gives the amount of gas A (in gal) for c miles of city driving and h miles of highway driving. In the formula, A, c, and h are called **variables** and these represent values that are subject to change. The values $\frac{1}{48}$ and $\frac{1}{52}$ are called **constants** because their values do not change in the formula.

For a trip from Houston, Texas, to Dallas, Texas, a motorist travels 36 mi of city driving and 91 mi of highway driving. The amount of fuel used by this hybrid vehicle is given by

$$\begin{aligned} A &= \frac{1}{48}(36) + \frac{1}{52}(91) \\ &= 2.5 \text{ gal} \end{aligned}$$

The numbers used in day-to-day life such as those used to determine fuel consumption come from the set of real numbers, denoted by $\mathbb{R}$. A **set** is a collection of items called **elements.** The braces { and } are used to enclose the elements of a set. For example, {gold, silver, bronze} represents the set of medals awarded to the top three finishers in an Olympic event. A set that contains no elements is called the **empty set** (or **null set**) and is denoted by { } or $\varnothing$.

When referring to individual elements of a set, the symbol $\in$ means "is an element of," and the symbol $\notin$ means "is not an element of." For example,

$5 \in \{1, 3, 5, 7\}$ is read as "5 is an element of the set of elements 1, 3, 5, and 7."

$6 \notin \{1, 3, 5, 7\}$ is read as "6 is *not* an element of the set of elements 1, 3, 5, and 7."

A set can be defined in several ways. Listing the elements in a set within braces is called the **roster method.** Using the roster method, the set of the even numbers between 0 and 10 is represented by {2, 4, 6, 8}. Another method to define this set is by using **set-builder notation.** This uses a description of the elements of the set. For example,

$$\{x \mid x \text{ is an even number between 0 and 10}\}$$

The set of all x such that x is an even number between 0 and 10

In our study of college algebra, we will often refer to several important **subsets** (parts of) the set of real numbers (Table R-1).

Table R-1 Subsets of the Set of Real Numbers, $\mathbb{R}$

Set	Definition
Natural numbers, $\mathbb{N}$	$\{1, 2, 3, \ldots\}$
Whole numbers, $\mathbb{W}$	$\{0, 1, 2, 3, \ldots\}$
Integers, $\mathbb{Z}$	$\{\ldots, -3, -2, -1, 0, 1, 2, 3, \ldots\}$
Rational numbers, $\mathbb{Q}$	$\left\{\frac{p}{q} \middle\| p, q \in \mathbb{Z} \text{ and } q \neq 0\right\}$ • Rational numbers can be expressed as a ratio of integers where the denominator is not zero. Examples: $-\frac{6}{11}$ (ratio of -6 and 11) and 9 (ratio of 9 and 1). • All terminating and repeating decimals are rational numbers. Examples: 0.71 (ratio of 71 and 100), $0.\overline{6} = 0.666\ldots$ (ratio of 2 and 3).
Irrational numbers, $\mathbb{H}$	Irrational numbers are real numbers that cannot be expressed as a ratio of integers. The decimal form of an irrational number is nonterminating and nonrepeating. Examples: π and $\sqrt{2}$

TIP Notice that the first five letters of the word *rational* spell *ratio*. This will help you remember that a rational number is a *ratio* of integers.