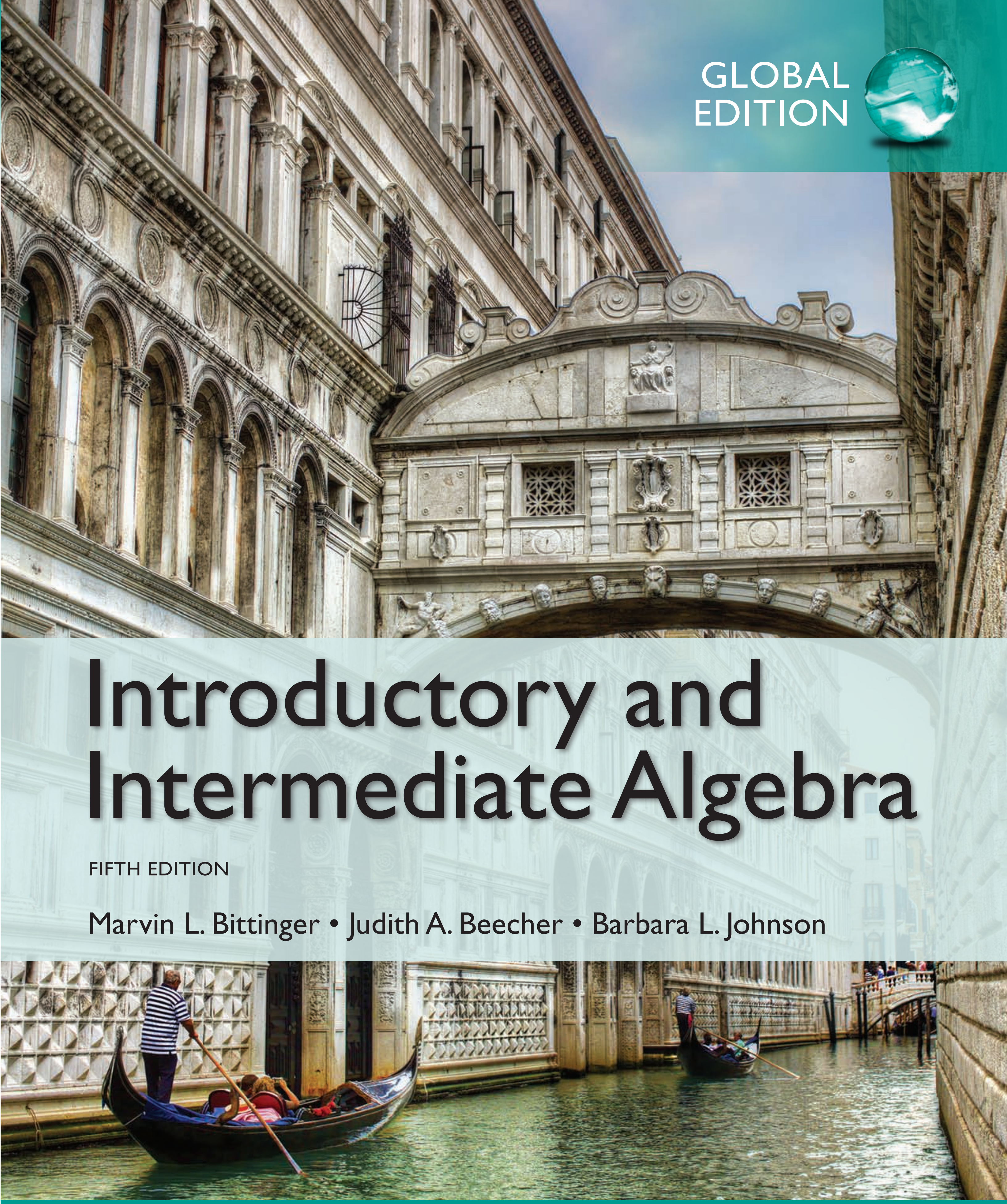

GLOBAL EDITION

Introductory and Intermediate Algebra

FIFTH EDITION

Marvin L. Bittinger • Judith A. Beecher • Barbara L. Johnson

ALWAYS LEARNING

PEARSON

Introductory and Intermediate Algebra

Fifth Edition

Global Edition

Marvin L. Bittinger

Indiana University Purdue University Indianapolis

Judith A. Beecher

Barbara L. Johnson

Indiana University Purdue University Indianapolis

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Authorized adaptation from the United States edition, entitled Intermediate Algebra, ISBN 978-0-321-91789-8, by Marvin L. Bittinger, Judith A. Beecher, and Barbara L. Johnson, published by Pearson Education © 2015.

ISBN 10: 1-292-08000-0
ISBN 13: 978-1-292-08000-0

10 9 8 7 6 5 4 3 2 1
14 13 12 11 10

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Typeset in 10 UtopiaStd-Regular by Lumina Datamatics, Ltd.

Printed in China (CTPS).

The publisher's policy is to use paper manufactured from sustainable forests.

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Preface

The Bittinger Program

Math hasn't changed, but students—and the way they learn it—have.

Introductory and Intermediate Algebra, Fifth Edition, continues the Bittinger tradition of objective-based, guided learning, while integrating timely updates to the proven pedagogy. In this edition, there is a greater emphasis on guided learning and helping students get the most out of all of the course resources available with the Bittinger program, including new opportunities for mobile learning.

The program has expanded to include these comprehensive new teaching and learning resources: ***MyMathGuide* workbook**, **To-the-Point Objective Videos**, and enhanced, media-rich **MyMathLab** courses. Feedback from instructors and students motivated these and several other significant improvements: a new design to support guided learning, new figures and photos to help students visualize both concepts and applications, and many new and updated real-data applications to bring the math to life.

With so many resources available in so many formats, the trusted guidance of the Bittinger team on *what to do* and *when* will help today's math students stay on task. Students are encouraged to use ***Your Guide to Success in Math***, a four-step learning path and checklist available on the handy reference card in the front of this text and in MyMathLab. The guide will help students identify the resources in the textbook, supplements, and MyMathLab that support *their* learning style, as they develop and retain the skills and conceptual understanding they need to succeed in this and future courses.

In this preface, a look at the key new *and* hallmark resources and features of the *Introductory and Intermediate Algebra* program—including the textbook/eText, video program, *MyMathGuide* workbook, and MyMathLab—is organized around ***Your Guide to Success in Math***. This will help instructors direct students to the tools and resources that will help them most in a traditional lecture, hybrid, lab-based, or online environment.

NEW AND HALLMARK FEATURES IN RELATION TO *Your Guide to Success in Math*

STEP 1 Learn the Skills and Concepts

Students have several options for learning, reviewing, and practicing the math concepts and skills.

Textbook/eText

- ☐ **Skill to Review.** At the beginning of nearly every text section, *Skill to Review* offers a just-in-time review of a previously presented skill that relates to the new material in the section. Section and objective references are included for the student's convenience, and two practice exercises are provided for review and reinforcement.
- ☐ **Margin Exercises.** For each objective, problems labeled "Do Exercise . . ." give students frequent opportunities to solve exercises while they learn.

- ☐ *New!* **Guided Solutions.** Nearly every section has *Guided Solution* margin exercises with fill-in blanks at key steps in the problem-solving process.
- ☐ *Enhanced!* **MyMathLab.** MyMathLab now includes *Active Learning Figures* for directed exploration of concepts; more problem types, including *Reading Checks* and *Guided Solutions*; and new, objective-based videos. (See pp. 16–19 for a detailed description of the features of MyMathLab.)
  - ☐ *New!* **Skills Checks.** In the Learning Path for Ready-to-Go MyMathLab, each chapter begins with a brief assessment of students' mastery of the prerequisite skills needed to learn the new material in the chapter. Based on the results of this pre-test, a personalized homework set is designed to help each student prepare for the chapter.
- ☐ *New!* **To-the-Point Objective Videos.** This is a comprehensive new program of objective-based, interactive videos that are incorporated into the Learning Path in MyMathLab and can be used hand-in-hand with the *MyMathGuide* workbook.
  - ☐ *New!* **Interactive Your Turn Exercises.** For each objective in the videos, students solve exercises and receive instant feedback on their work.
- ☐ *New!* ***MyMathGuide: Notes, Practice, and Video Path.*** This is an objective-based workbook (available printed and in MyMathLab) for guided, hands-on learning. It offers vocabulary, skill, and concept review—along with problem-solving practice—with space to show work and write notes. Incorporated in the Learning Path in MyMathLab, it can be used together with the To-the-Point Objective Video program, instructor lectures, and the textbook.

STEP 2 Check Your Understanding

Throughout the program, students have frequent opportunities to check their work and confirm that they understand each skill and concept before moving on to the next topic.

- ☐ *New!* **Reading Checks.** At the beginning of each set of section exercises in the text, students demonstrate their grasp of the skills and concepts.
- ☐ *New!* **Active Learning Figures.** In MyMathLab, Active Learning Figures guide students in exploring math concepts and reinforcing their understanding.
- ☐ **Translating/Visualizing for Success.** In the text and in MyMathLab, these activities offer students extra practice with the important first step of the process for solving applied problems.

STEP 3 Do Your Homework

Introductory and Intermediate Algebra, Fifth Edition, has a wealth of proven and updated exercises. Prebuilt assignments are available for instructors in MyMathLab, and they are preassigned and incorporated into the Learning Path in the Ready-to-Go course.

- ☐ **Skill Maintenance.** In each section, these exercises offer a thorough review of the math in the preceding text.
- ☐ **Synthesis Exercises.** To help build critical-thinking skills, these section exercises require students to use what they know and combine learning objectives from the current section with those from previous sections.

STEP 4 **Review and Test Your Understanding**

Students have a variety of resources to check their skills and understanding along the way and to help them prepare for tests.

- **Mid-Chapter Review.** Mid-way through each chapter, students work a set of exercises (*Concept Reinforcement, Guided Solutions, Mixed Review,* and *Understanding Through Discussion and Writing*) to confirm that they have grasped the skills and concepts covered in the first half before moving on to new material.
- **Summary and Review.** This resource provides an in-text opportunity for active learning and review for each chapter. *Vocabulary Reinforcement, Concept Reinforcement,* objective-based *Study Guide* (examples paired with similar exercises), *Review Exercises* (including *Synthesis* problems), and *Understanding Through Discussion and Writing* are included in these comprehensive chapter reviews.
- **Chapter Test.** Chapter Tests offer students the opportunity for comprehensive review and reinforcement prior to taking their instructor's exam. **Chapter Test-Prep Videos** (in MyMathLab and on YouTube) show step-by-step solutions to the Chapter Tests.
- **Cumulative Review.** Following every chapter beginning with Chapter 2, a Cumulative Review revisits skills and concepts from all preceding chapters to help students retain previously learned material.

Study Skills

Developing solid time-management, note-taking, test-taking, and other study skills is key to student success in math courses (as well as professionally and personally). Instructors can direct students to related study skills resources as needed.

- ***New!*** **Student Study Reference.** This pull-out card at the front of the text is perforated, three-hole-punched, and binder-ready for convenient reference. It includes **Your Guide to Success in Math** course checklist, **Student Organizer**, and **At a Glance**, a list of key information and expressions for quick reference as students work exercises and review for tests.
- ***New!*** **Studying for Success.** Checklists of study skills—designed to ensure that students develop the skills they need to succeed in math, school, and life—are integrated throughout the text at the beginning of selected sections.
- ***New!*** **Study Skills Modules.** In MyMathLab, interactive modules address common areas of weakness, including time-management, test-taking, and note-taking skills. Additional modules support career-readiness.

Learning Math in Context

- ***New!*** **Applications.** Throughout the text in examples and exercises, real-data applications encourage students to see and interpret the mathematics that appears every day in the world around them. Applications that use real data are drawn from business and economics, life and physical sciences, medicine, technology, and areas of general interest such as sports and daily life. New applications include "Cycling in Vietnam" (p. 147), "Speed of Sea Animals" (p. 477), "Employment Demand for Physical Therapists" (p. 655), "Beach Volleyball" (p. 815), and "Alternative Fueling Stations" (p. 898). For a complete list of applications, please refer to the Index of Applications (p. 7).

BREAKTHROUGH
To improving results

MyMathLab

Ties the Complete Learning Program Together

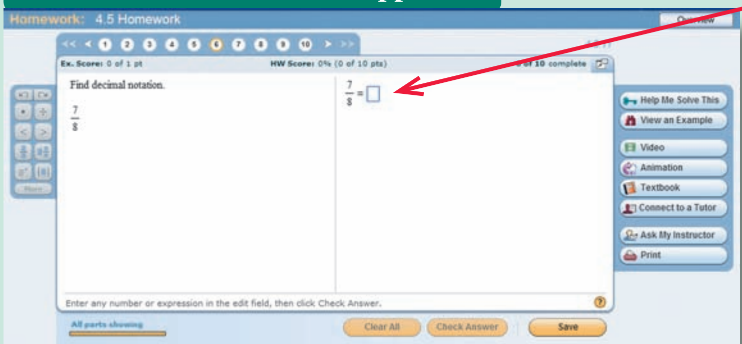
MyMathLab® Online Course (access code required)
MyMathLab from Pearson is the world's leading online resource in mathematics, integrating interactive homework, assessment, and media in a flexible, easy to use format. MyMathLab delivers **proven results** in helping individual students succeed. It provides **engaging experiences** that personalize, stimulate, and measure learning for each student. And it comes from an **experienced partner** with educational expertise and an eye on the future.

MyMathLab for Developmental Mathematics

Prepared to go wherever you want to take your students.

Personalized Support for Students

Homework with Built-in Support

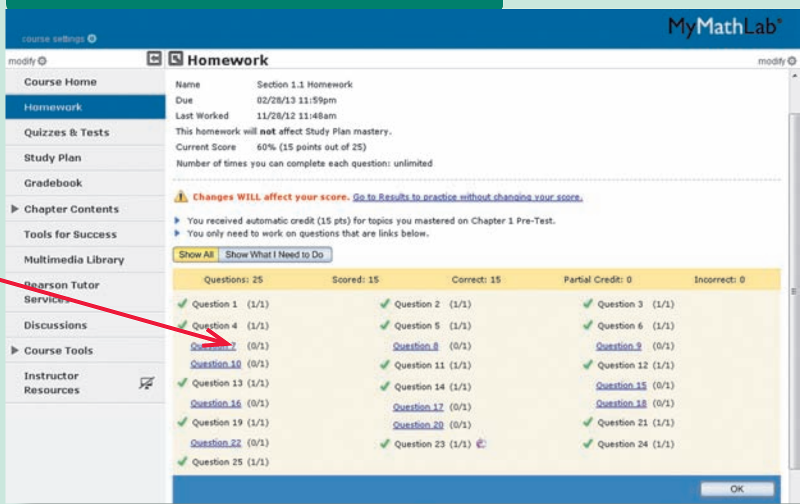


Exercises: The homework and practice exercises in MyMathLab are correlated to the exercises in the textbook, and they regenerate algorithmically to give students unlimited opportunities for practice and mastery. The software offers immediate, helpful feedback when students enter incorrect answers.

Multimedia Learning Aids: Exercises include guided solutions, sample problems, animations, videos, and eText access for extra help at point-of-use.

Expert Tutoring: Although many students describe the whole of MyMathLab as "like having your own personal tutor," students using MyMathLab do have access to live tutoring from qualified math instructors.

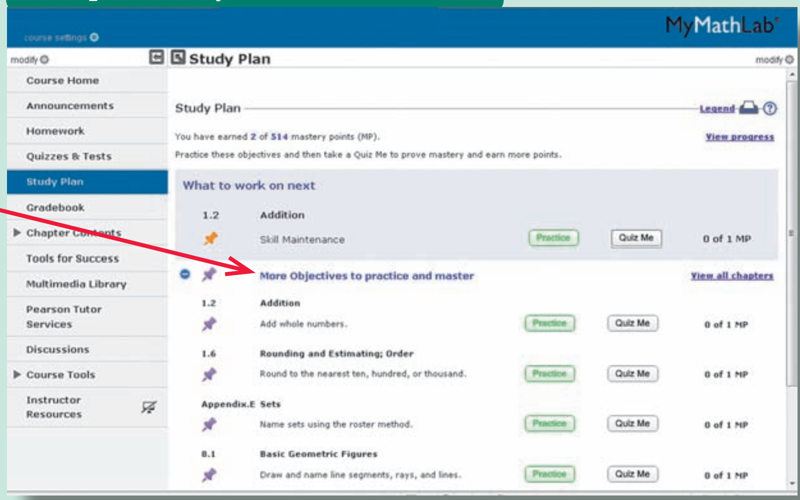
Personalized Homework



To help students achieve mastery, MyMathLab can generate **personalized homework** based on individual performance on tests or quizzes. Personalized homework allows students to focus on topics they have not yet mastered.

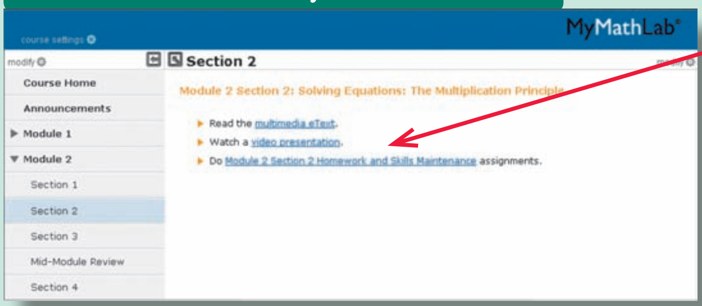
The **Adaptive Study Plan** makes studying more efficient and effective for every student. Performance and activity are assessed continually in real time. The data and analytics are used to provide personalized content—reinforcing concepts that target each student's strengths and weaknesses.

Adaptive Study Plan



Flexible Design, Easy Start-Up, and Results for Instructors

Customized and Ready-to-Go Courses



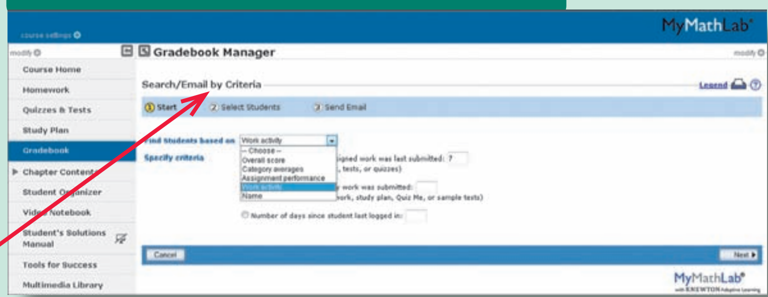
Instructors can modify the site navigation and insert their own directions on course-level landing pages; also, a **custom MyMathLab** course can be built that reorganizes and structures the course material by chapters, modules, units—whatever the need may be.

Ready-to-Go courses include preassigned homework, quizzes, and tests to make it even easier to get started. The Bittinger Ready-to-Go courses include new *Mid-Chapter Reviews* and *Reading Check Assignments*, plus a four-step Learning Path on each section-level landing page to help instructors direct students where to go and what resources to use.

The **comprehensive online gradebook** automatically tracks students' results on tests, quizzes, and homework and in the study plan. Instructors can use the gradebook to quickly intervene if students have trouble, or to provide positive feedback on a job well done. The data within MyMathLab are easily exported to a variety of spreadsheet programs, such as Microsoft Excel.® Instructors can determine which points of data to export and then analyze the results to determine success.

New features, such as **Search/Email by criteria**, make the gradebook a powerful tool for instructors. With this feature, instructors can easily communicate with both at-risk and successful students. They can search by score on specific assignments, noncompletion of assignments within a given time frame, last login date, or overall score.

Gradebook

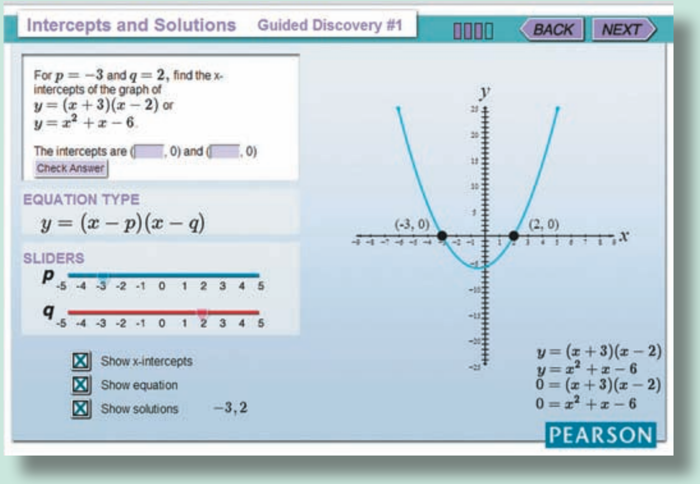


Special Bittinger Resources
in MyMathLab for Students and Instructors

In addition to robust course delivery, MyMathLab offers the full Bittinger eText, additional Bittinger Program features, and the entire set of instructor and student resources in one easy-to-access online location.

New! Active Learning Figures

In MyMathLab, Active Learning Figures guide students in exploring math concepts and reinforcing their understanding. Instructors can use Active Learning Figures in class or as media assignments in MyMathLab.



New! Four-Step Learning Path

Each of the section-level landing pages in the Ready-to-Go MyMathLab course includes a Learning Path that aligns with *Your Guide to Success in Math* to link students directly to the resources they should use when they need them. This also allows instructors to point students to the best resources to use at particular times.

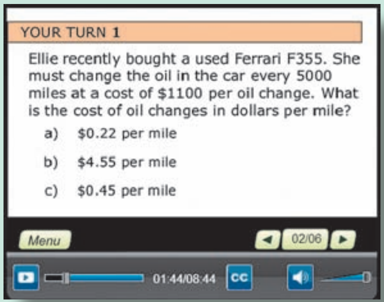
New! Integrated Bittinger Video Program and *MyMathGuide* workbook

Bittinger Video Program

The Video Program is available in MyMathLab and includes closed captioning and the following video types:

New! To-the-Point Objective Videos. These objective-based, interactive videos are incorporated into the Learning Path in MyMathLab and can be used along with the *MyMathGuide* workbook.

Chapter Test Prep Videos. The Chapter Test Prep Videos let students watch instructors work through step-by-step solutions to all the Chapter Test exercises from the textbook. Chapter Test Prep Videos are also available on YouTube (search using author name and book title).



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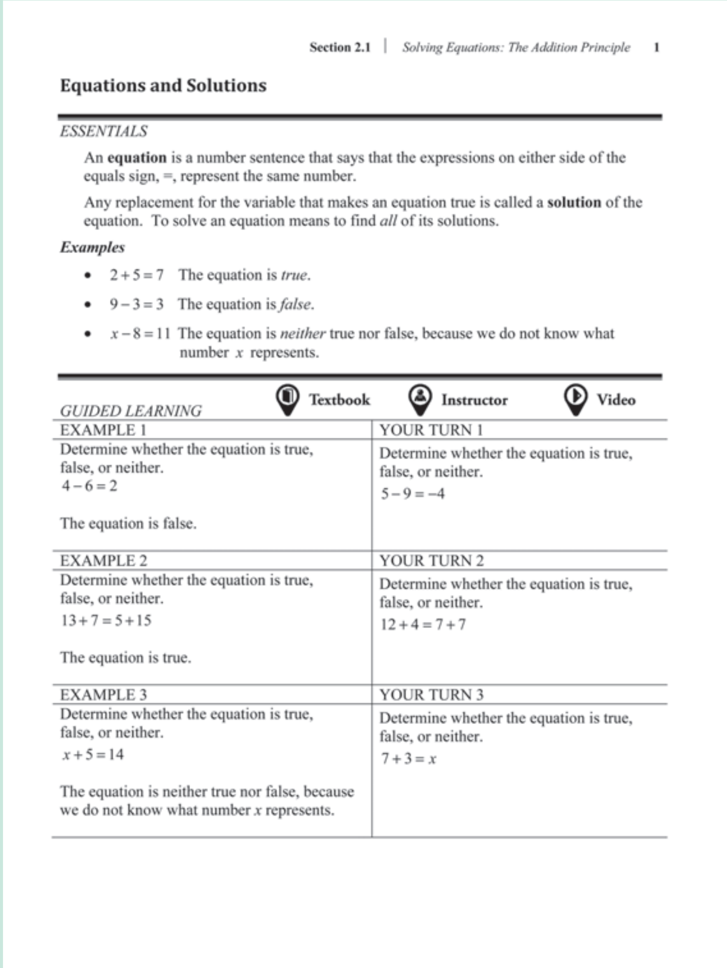
This objective-based workbook for guided, hands-on learning offers vocabulary, skill, and concept review—along with problem-solving practice—with space to show work and write notes. Incorporated in the Learning Path in MyMathLab, *MyMathGuide* can be used together with the To-the-Point Objective Video program, instructor lectures, and the textbook. Instructors can assign To-the-Point Objective Videos in MyMathLab in conjunction with the *MyMathGuide* workbook.



Section 2.1 | *Solving Equations: The Addition Principle* **1**

Equations and Solutions

ESSENTIALS

An **equation** is a number sentence that says that the expressions on either side of the equals sign, =, represent the same number.

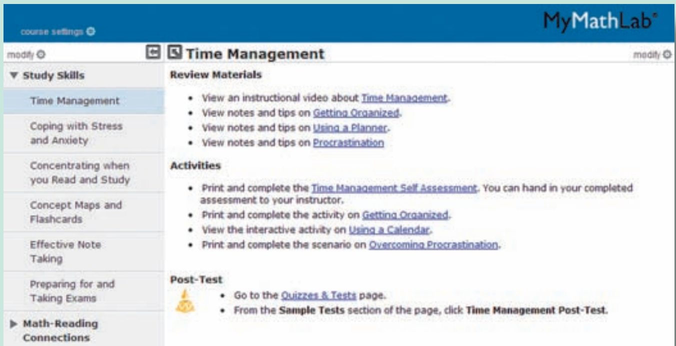
Any replacement for the variable that makes an equation true is called a **solution** of the equation. To solve an equation means to find *all* of its solutions.

Examples

- $2+5=7$ The equation is *true*.
- $9-3=3$ The equation is *false*.
- $x-8=11$ The equation is *neither* true nor false, because we do not know what number x represents.

GUIDED LEARNING Textbook Instructor Video

EXAMPLE 1	YOUR TURN 1
Determine whether the equation is true, false, or neither. $4-6=2$ The equation is false.	Determine whether the equation is true, false, or neither. $5-9=-4$
EXAMPLE 2	YOUR TURN 2
Determine whether the equation is true, false, or neither. $13+7=5+15$ The equation is true.	Determine whether the equation is true, false, or neither. $12+4=7+7$
EXAMPLE 3	YOUR TURN 3
Determine whether the equation is true, false, or neither. $x+5=14$ The equation is neither true nor false, because we do not know what number x represents.	Determine whether the equation is true, false, or neither. $7+3=x$



Study Skills Modules

In MyMathLab, interactive modules address common areas of weakness, including time-management, test-taking, and note-taking skills. Additional modules support career-readiness. Instructors can assign module material with a post-quiz.

Additional Resources in MyMathLab

For Students

Student's Solutions Manual

By Judy Penna

Contains completely worked-out annotated solutions for all the odd-numbered exercises in the text. Also includes fully worked-out annotated solutions for all the exercises (odd- and even-numbered) in the Mid-Chapter Reviews, the Summary and Reviews, the Chapter Tests, and the Cumulative Reviews.

For Instructors

Instructor's Resource Manual with Tests and Mini Lectures**

(download only)

By Laurie Hurley

This manual includes resources designed to help both new and experienced instructors with course preparation and classroom management. This includes chapter-by-chapter teaching tips and support for media supplements. Contains two multiple-choice tests per chapter, six free-response tests per chapter, and eight final exams.

Instructor's Solutions Manual**

(download only)

By Judy Henn

This manual contains detailed, worked-out solutions to all odd-numbered exercises and brief solutions to the even-numbered exercises in the exercise sets.

PowerPoint® Lecture Slides**

(download only)

Present key concepts and definitions from the text.

To learn more about how MyMathLab combines proven learning applications with powerful assessment, visit http://www.mymathlabglobal.com or contact your Pearson representative.

**Also available for download from the Instructor Resource Center (IRC) on www.pearsonglobaleditions.com/Bittinger.

Acknowledgments

Our deepest appreciation to all of you who helped to shape this edition by reviewing and spending time with us on your campuses. In particular, we would like to thank the following reviewers:

Nneka Anigbogu, *Malcolm X College*
Afsheen Akbar, *Bergen Community College*
Michael Bagley, *Feather River College*
Susan Bornsen, *North Dakota State University*
Erin Cooke, *Gwinnett Technical College*
Kay Davis, *Del Mar College*
Beverlee Drucker, *Northern Virginia Community College*
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Mary Pat Sheppard, *Malcolm X College*
Melanie Walker, *Bergen Community College*
Limin Zhang, *Columbia Basin College*

The endless hours of hard work by Martha Morong and Geri Davis have led to products of which we are immensely proud. We also want to thank Judy Penna for writing the Student's and Instructor's Solutions Manuals. Other strong support has come from Laurie Hurley for the *Instructor's Resource Manual* and for accuracy checking, along with checkers Judy Penna, Joanna Eichenwald, and Perian Herring, and from proofreader Daniel Johnson. Michelle Lanosga assisted with applications research. We also wish to recognize Nelson Carter, Tom Atwater, Judy Penna, and Laurie Hurley who prepared the videos.

In addition, a number of people at Pearson have contributed in special ways to the development and production of this textbook, including the Developmental Math team: Senior Production Supervisor Ron Hampton, Senior Designer Barbara Atkinson, Content Editor Katherine Minton, Editorial Assistant Chase Hammond, and Associate Media Producer Jonathan Wooding. Executive Editor Cathy Cantin and Marketing Manager Rachel Ross encouraged our vision and provided marketing insight.

The publishers would like to thank the following for their contributions to the Global Edition:

Contributor

Pranab Sarma, *Assam Engineering College*

Reviewers

Mani Sankar, *East Point College of Engineering and Technology*
C.V. Vinay, *JSS Academy of Technical Education*
Vini Chharia

At a Glance: Introductory and Intermediate Algebra

Operations with Real Numbers

$-18 + 3 = -15$

$-6 + (-4) = -10$

$9 - 12 = -3$

$-7 - (-10) = 3$

$-9 \cdot 6 = -54$

$-5 \cdot (-3) = 15$

$18 \div (-3) = -6$

$-10 \div (-2) = 5$

Absolute value: $|-4| = 4$

The opposite of $-\frac{3}{7}$ is $\frac{3}{7}$.

The reciprocal of $-\frac{2}{9}$ is $-\frac{9}{2}$.

Order of Operations

1. Do all calculations within grouping symbols before operations outside.
2. Evaluate all exponential expressions.
3. Do all multiplications and divisions in order from left to right.
4. Do all additions and subtractions in order from left to right.

Exponents

$x^0 = 1;\quad x^1 = x;\quad x^{-3} = \frac{1}{x^3};$

$x^2 \cdot x^5 = x^7;\quad \frac{x^5}{x^2} = x^3;\quad (x^2)^5 = x^{10}$

Polynomials

Multiplying:

$(y - 4)(3y + 5) = 3y^2 - 7y - 20$

$(q - 5)(q + 5) = q^2 - 25$

$(2a - 3)^2 = 4a^2 - 12a + 9$

Factoring:

$2x^2 - 5x - 12 = (2x + 3)(x - 4)$

$25x^2 - 4 = (5x - 2)(5x + 2)$

$9x^2 + 6x + 1 = (3x + 1)^2$

$x^3 + 64 = (x + 4)(x^2 - 4x + 16)$

$x^3 - 1000 = (x - 10)(x^2 + 10x + 100)$

Set-Builder Notation and Interval Notation

$\{x \mid x \text{ is a real number}\} = (-\infty, \infty)$

$\{x \mid x < 3\} = (-\infty, 3)$

$\{x \mid -3 \le x < 3\} = [-3, 3)$

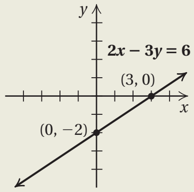
$\{x \mid x \ge 3\} = [3, \infty)$

Linear Function and Slope

$Ax + By = C$: $2x - 3y = 6$;

$y = mx + b$: $y = \frac{2}{3}x - 2$;

$f(x) = mx + b$: $f(x) = \frac{2}{3}x - 2$



Slope $(m) = \frac{2}{3}$

y-intercept $(0, b) = (0, -2)$

Slope of line through $(-6, 2)$ and $(4, -9)$:

$$m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{-9 - 2}{4 - (-6)} = \frac{-11}{10} = -\frac{11}{10}$$

The slope of a horizontal line is 0.

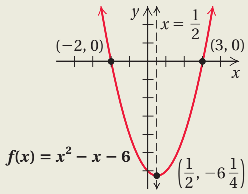
The slope of a vertical line is not defined.

Quadratic Functions

$f(x) = ax^2 + bx + c$

$f(x) = x^2 - x - 6$

$\quad\;\; = (x + 2)(x - 3)$



Function values:

$f(0) = -6$, $f(1) = -6$,

$f(-2) = 0$, $f(3) = 0$,

$f(-1) = -4$, $f(2) = -4$

x-intercepts: $(-2, 0)$ and $(3, 0)$

Vertex: $\left(-\frac{b}{2a}, f\left(-\frac{b}{2a}\right)\right) = \left(\frac{1}{2}, -6\frac{1}{4}\right)$

Axis of symmetry: $x = \frac{1}{2}$

Domain: $(-\infty, \infty)$

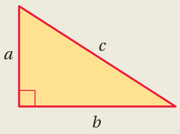
Range: $\left[-6\frac{1}{4}, \infty\right)$

Parallel Lines and Perpendicular Lines

Two lines are parallel if they have the same slope and different y-intercepts;
$y = 2x - 3$ and $y = 2x + 4$ are parallel.

Two nonvertical lines are perpendicular if the product of their slopes is -1: $m_1 \cdot m_2 = -1$;
$y = \frac{1}{2}x + 3$ and $y = -2x - 7$ are perpendicular.

Pythagorean Theorem



$$a^2 + b^2 = c^2$$

Solving Equations

Using the Principle of Zero Products

$$\begin{aligned} x^2 + 3x &= 54 \\ x^2 + 3x - 54 &= 0 \\ (x + 9)(x - 6) &= 0 \\ x + 9 = 0 \quad &\textit{or} \quad x - 6 = 0 \\ x = -9 \quad &\textit{or} \quad x = 6 \end{aligned}$$

The solutions are -9 and 6.

Using the Quadratic Formula

Quadratic Formula: $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$x^2 - 6x + 2 = 0;\ a = 1, b = -6, c = 2$

$$x = \frac{-(-6) \pm \sqrt{(-6)^2 - 4 \cdot 1 \cdot 2}}{2 \cdot 1} = \frac{6 \pm \sqrt{28}}{2}$$

$$= \frac{6 \pm 2\sqrt{7}}{2} = 3 \pm \sqrt{7}$$

The solutions are $3 + \sqrt{7}$ and $3 - \sqrt{7}$, or $3 \pm \sqrt{7}$.

Containing Absolute Value

$$\begin{aligned} |x - 2| &= 5 \\ x - 2 = -5 \quad &\textit{or} \quad x - 2 = 5 \\ x = -3 \quad &\textit{or} \quad x = 7 \end{aligned}$$

The solutions are -3 and 7.

Multiplying by the LCM

$$\begin{aligned} \frac{5}{4x} + \frac{1}{x} &= 2 \\ 4x \cdot \left(\frac{5}{4x} + \frac{1}{x}\right) &= 4x \cdot 2 \\ 5 + 4 &= 8x \\ 9 &= 8x \\ \frac{9}{8} &= x \end{aligned}$$

The solution is $\frac{9}{8}$.

Using the Principle of Powers

$$\begin{aligned} \sqrt{x - 1} - 3 &= 9 \\ \sqrt{x - 1} &= 12 \\ (\sqrt{x - 1})^2 &= 12^2 \\ x - 1 &= 144 \\ x &= 145 \end{aligned}$$

The solution is 145.

Solving Systems of Equations Using the Elimination Method

$$\begin{aligned} x - 3y = -7 \quad &\longrightarrow \quad -2x + 6y = 14 \\ 2x + 5y = -3 \quad &\longrightarrow \quad \underline{\ \ 2x + 5y = -3} \\ & \qquad\qquad\quad 11y = 11 \\ & \qquad\qquad\qquad y = 1 \end{aligned}$$

Substitute 1 for y in either equation and solve for x:

$$\begin{aligned} 2x + 5 \cdot 1 &= -3 \\ 2x &= -8 \\ x &= -4. \end{aligned}$$

The solution is $(-4, 1)$.

Solving Inequalities

Using the Addition Principle and the Multiplication Principle

$$\begin{aligned} -5x + 2 &\le -78 \\ -5x &\le -80 \\ x &\ge 16 \end{aligned}$$

The solution set is $\{x \mid x \ge 16\}$, or $[16, \infty)$.

Containing Absolute Value

$$\begin{aligned} |x - 2| &\le 5 \\ -5 \le x - 2 &\le 5 \\ -3 \le x &\le 7 \end{aligned}$$

The solution set is $\{x \mid -3 \le x \le 7\}$, or $[-3, 7]$.

$$\begin{aligned} |x - 2| &> 5 \\ x - 2 < -5 \quad &\textit{or} \quad x - 2 > 5 \\ x < -3 \quad &\textit{or} \quad x > 7 \end{aligned}$$

The solution set is $\{x \mid x < -3 \textit{ or } x > 7\}$, or $(-\infty, -3) \cup (7, \infty)$.

Variation

Direct: $y = kx;\ y = 6x$

Inverse: $y = \dfrac{k}{x};\ y = \dfrac{2}{x}$

Joint: $y = kxz;\ y = 9xz$

Complex Numbers

$i = \sqrt{-1};\ i^2 = -1$

$(2 - 3i) + (6 + 2i) = 8 - i$

$\sqrt{-4} \cdot \sqrt{-15} = 2i \cdot \sqrt{15}i = 2\sqrt{15}i^2 = -2\sqrt{15}$

$\dfrac{-3 + 4i}{1 - 6i} = \dfrac{-3 + 4i}{1 - 6i} \cdot \dfrac{1 + 6i}{1 + 6i} = \dfrac{-27 - 14i}{1 - 36i^2} = -\dfrac{27}{37} - \dfrac{14}{37}i$

Properties of Logarithms

Product Rule: $\log_a(M \cdot N) = \log_a M + \log_a N$

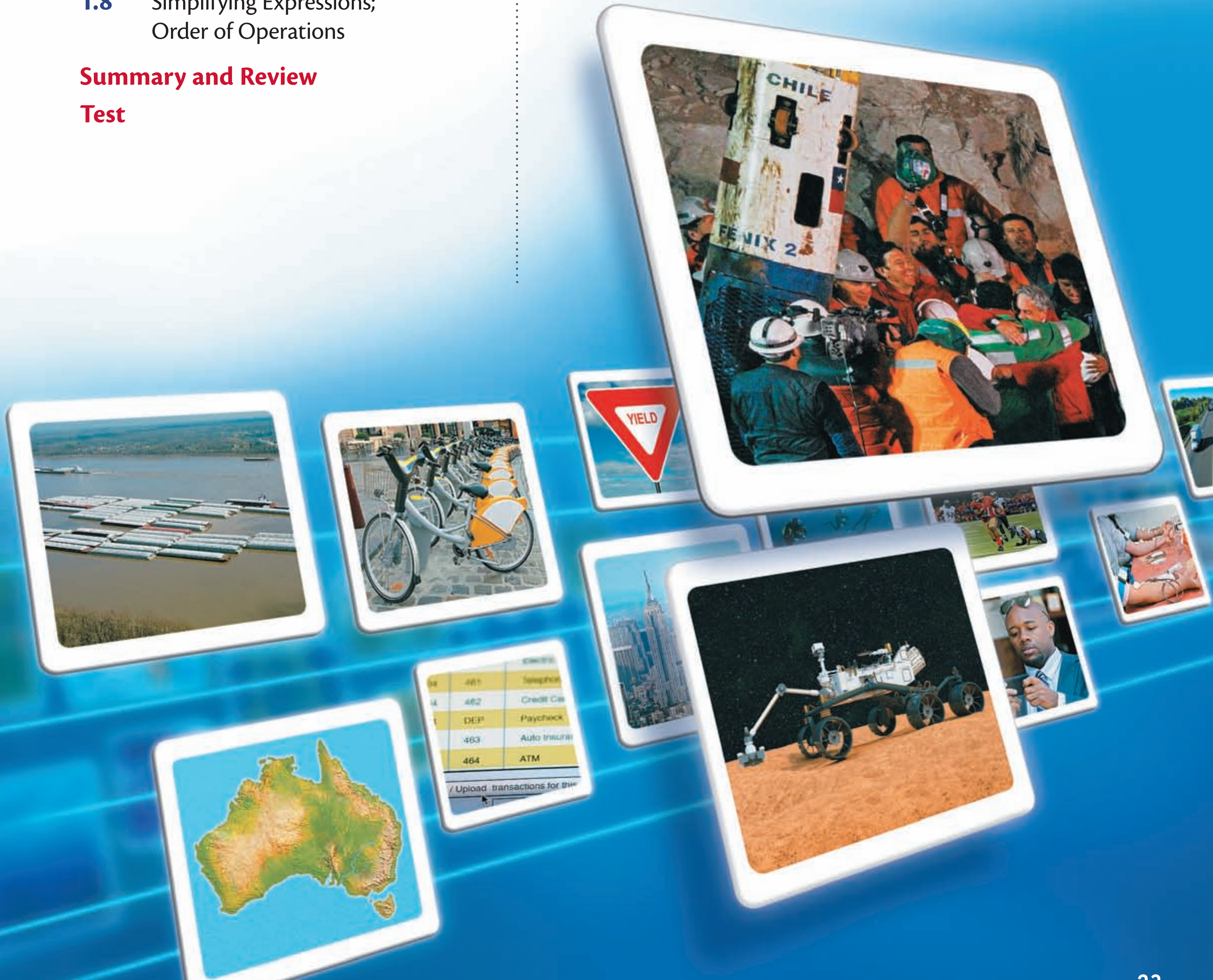
Power Rule: $\log_a M^k = k \cdot \log_a M$

Quotient Rule: $\log_a \dfrac{M}{N} = \log_a M - \log_a N$

CHAPTER

1

Introduction to Real Numbers and Algebraic Expressions



STUDYING FOR SUCCESS *Getting Off to a Good Start*

- Your syllabus for this course is extremely important. Read it carefully, noting required texts and materials.
- If you have an online component in your course, register for it as soon as possible.
- At the front of the text, you will find a Student Organizer card. This pullout card will help you keep track of important dates and useful contact information.

1.1 Introduction to Algebra

OBJECTIVES

a Evaluate algebraic expressions by substitution.

b Translate phrases to algebraic expressions.

The study of algebra involves the use of equations to solve problems. Equations are constructed from algebraic expressions.

a EVALUATING ALGEBRAIC EXPRESSIONS

In arithmetic, you have worked with expressions such as

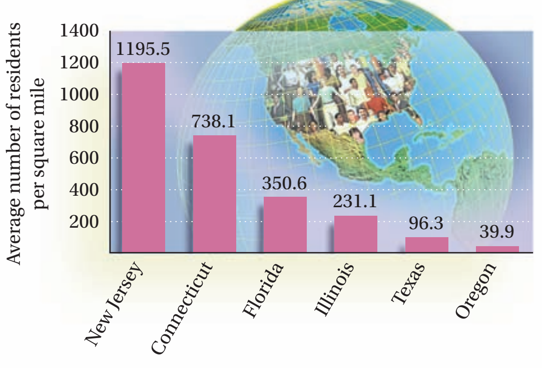
$$49 + 75, \quad 8 \times 6.07, \quad 29 - 14, \quad \text{and} \quad \frac{5}{6}.$$

In algebra, we can use letters to represent numbers and work with *algebraic expressions* such as

$$x + 75, \quad 8 \times y, \quad 29 - t, \quad \text{and} \quad \frac{a}{b}.$$

Sometimes a letter can represent various numbers. In that case, we call the letter a **variable**. Let $a =$ your age. Then a is a variable since a changes from year to year. Sometimes a letter can stand for just one number. In that case, we call the letter a **constant**. Let $b =$ your date of birth. Then b is a constant.

Population Density



SOURCE: 2010 U.S. Census

Where do algebraic expressions occur? Most often we encounter them when we are solving applied problems. For example, consider the bar graph shown at left, one that we might find in a book or a magazine. Suppose we want to know how much greater the average population density per square mile is in New Jersey than in Illinois. Using arithmetic, we might simply subtract. But let's see how we can determine this using algebra. We translate the problem into a statement of equality, an equation. It could be done as follows:

$$\underbrace{\text{Population density in Illinois}}_{231.1} \;\underbrace{\text{plus}}_{+}\; \underbrace{\text{How much more}}_{x} \;\underbrace{\text{is}}_{=}\; \underbrace{\text{Population density in New Jersey}}_{1195.5.}$$

Note that we have an algebraic expression, $231.1 + x$, on the left of the equals sign. To find the number x, we can subtract 231.1 on both sides of the equation:

$$231.1 + x = 1195.5$$
$$231.1 + x - 231.1 = 1195.5 - 231.1$$
$$x = 964.4.$$

This value of x gives the answer, 964.4 residents per square mile.

We call $231.1 + x$ an *algebraic expression* and $231.1 + x = 1195.5$ an *algebraic equation*. Note that there is no equals sign, $=$, in an algebraic expression.

Do Margin Exercise 1. ▶

An **algebraic expression** consists of variables, constants, numerals, operation signs, and/or grouping symbols. When we replace a variable with a number, we say that we are **substituting** for the variable. When we replace all of the variables in an expression with numbers and carry out the operations in the expression, we are **evaluating the expression**.

EXAMPLE 1 Evaluate $x + y$ when $x = 37$ and $y = 29$.

We substitute 37 for x and 29 for y and carry out the addition:

$$x + y = 37 + 29 = 66.$$

The number 66 is called the **value** of the expression when $x = 37$ and $y = 29$.

Algebraic expressions involving multiplication can be written in several ways. For example, "8 times a" can be written as

$$8 \times a, \quad 8 \cdot a, \quad 8(a), \quad \text{or simply} \quad 8a.$$

Two letters written together without an operation symbol, such as ab, also indicate a multiplication.

EXAMPLE 2 Evaluate $3y$ when $y = 14$.

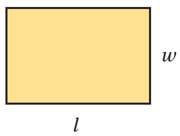
$$3y = 3(14) = 42$$

Do Exercises 2–4. ▶

EXAMPLE 3 ***Area of a Rectangle.*** The area A of a rectangle of length l and width w is given by the formula $A = lw$. Find the area when l is 24.5 in. and w is 16 in.

We substitute 24.5 in. for l and 16 in. for w and carry out the multiplication:

$$\begin{aligned} A = lw &= (24.5 \text{ in.})(16 \text{ in.}) \\ &= (24.5)(16)(\text{in.})(\text{in.}) \\ &= 392 \text{ in}^2, \text{ or } 392 \text{ square inches.} \end{aligned}$$



Do Exercise 5. ▶

Algebraic expressions involving division can also be written in several ways. For example, "8 divided by t" can be written as

$$8 \div t, \quad \frac{8}{t}, \quad 8/t, \quad \text{or} \quad 8 \cdot \frac{1}{t},$$

where the fraction bar is a division symbol.

EXAMPLE 4 Evaluate $\frac{a}{b}$ when $a = 63$ and $b = 9$.

We substitute 63 for a and 9 for b and carry out the division:

$$\frac{a}{b} = \frac{63}{9} = 7.$$

1. Translate this problem to an equation. Then solve the equation.

Population Density. The average number of residents per square mile in six U.S. states is shown in the bar graph on the preceding page. How much greater is the population density in Connecticut than in Oregon?

2. Evaluate $a + b$ when $a = 38$ and $b = 26$.

3. Evaluate $x - y$ when $x = 57$ and $y = 29$.

4. Evaluate $4t$ when $t = 15$.

GS **5.** Find the area of a rectangle when l is 24 ft and w is 8 ft.

$A = lw$

$A = (24 \text{ ft})(\quad)$

$\quad = (24)(\quad)(\text{ft})(\text{ft})$

$\quad = 192 \quad$, or

192 square feet

Answers

1. $39.9 + x = 738.1$; 698.2 residents per square mile **2.** 64 **3.** 28 **4.** 60 **5.** 192 ft^2

Guided Solution:

5. 8 ft, 8, ft^2

6. Evaluate a/b when $a = 200$ and $b = 8$.

7. Evaluate $10p/q$ when $p = 40$ and $q = 25$.

8. ***Commuting via Bicycle.*** Find the time it takes to bike 22 mi if the speed is 16 mph.

EXAMPLE 5 Evaluate $\frac{12m}{n}$ when $m = 8$ and $n = 16$.

$$\frac{12m}{n} = \frac{12 \cdot 8}{16} = \frac{96}{16} = 6$$

◀ **Do Exercises 6 and 7.**

EXAMPLE 6 ***Commuting Via Bicycle.*** Commuting to work via bicycle has increased in popularity with the emerging concept of sharing bicycles. Bikes are picked up and returned at docking stations. The payment is approximately \$1.50 per 30 min. Richard bicycles 18 mi to work. The time t, in hours, that it takes to bike 18 mi is given by

$$t = \frac{18}{r},$$

where r is the speed. Find the time for Richard to commute to work if his speed is 15 mph.

We substitute 15 for r and carry out the division:

$$t = \frac{18}{r} = \frac{18}{15} = 1.2 \text{ hr.}$$

◀ **Do Exercise 8.**

b TRANSLATING TO ALGEBRAIC EXPRESSIONS

We translate problems to equations. The different parts of an equation are translations of word phrases to algebraic expressions. It is easier to translate if we know that certain words often translate to certain operation symbols.

Key Words, Phrases, and Concepts

ADDITION (+)	SUBTRACTION (−)	MULTIPLICATION (·)	DIVISION (÷)
add	subtract	multiply	divide
added to	subtracted from	multiplied by	divided by
sum	difference	product	quotient
total	minus	times	
plus	less than	of	
more than	decreased by		
increased by	take away		

EXAMPLE 7 Translate to an algebraic expression:

Twice (or two times) some number.

Think of some number, say, 8. We can write 2 times 8 as 2×8, or $2 \cdot 8$. We multiplied by 2. Do the same thing using a variable. We can use any variable we wish, such as $x, y, m,$ or n. Let's use y to represent some number. If we multiply by 2, we get an expression

$$y \times 2, \quad 2 \times y, \quad 2 \cdot y, \quad \text{or} \quad 2y.$$

Answers

6. 25 **7.** 16 **8.** 1.375 hr

EXAMPLE 8 Translate to an algebraic expression:

Thirty-eight percent of some number.

Let $n =$ the number. The word "of" translates to a multiplication symbol, so we could write any of the following expressions as a translation:

$38\% \cdot n, \quad 0.38 \times n, \quad \text{or} \quad 0.38n.$

EXAMPLE 9 Translate to an algebraic expression:

Seven less than some number.

We let x represent the number. If the number were 10, then 7 less than 10 is $10 - 7$, or 3. If we knew the number to be 34, then 7 less than the number would be $34 - 7$. Thus if the number is x, then the translation is

$x - 7.$

Caution!

Note that $7 - x$ is *not* a correct translation of the expression in Example 9. The expression $7 - x$ is a translation of "seven minus some number" or "some number less than seven."

EXAMPLE 10 Translate to an algebraic expression:

Eighteen more than a number.

We let $t =$ the number. If the number were 6, then the translation would be $6 + 18$, or $18 + 6$. If we knew the number to be 17, then the translation would be $17 + 18$, or $18 + 17$. Thus if the number is t, then the translation is

$t + 18, \quad \text{or} \quad 18 + t.$

EXAMPLE 11 Translate to an algebraic expression:

A number divided by 5.

We let $m =$ the number. If the number were 7, then the translation would be $7 \div 5$, or $7/5$, or $\frac{7}{5}$. If the number were 21, then the translation would be $21 \div 5$, or $21/5$, or $\frac{21}{5}$. If the number is m, then the translation is

$$m \div 5, \quad m/5, \quad \text{or} \quad \frac{m}{5}.$$

EXAMPLE 12 Translate each phrase to an algebraic expression.

PHRASE	ALGEBRAIC EXPRESSION
Five more than some number	$n + 5$, or $5 + n$
Half of a number	$\frac{1}{2}t$, $\frac{t}{2}$, or $t/2$
Five more than three times some number	$3p + 5$, or $5 + 3p$
The difference of two numbers	$x - y$
Six less than the product of two numbers	$mn - 6$
Seventy-six percent of some number	$76\%z$, or $0.76z$
Four less than twice some number	$2x - 4$

Do Exercises 9–17.

Translate each phrase to an algebraic expression.

9. Eight less than some number

10. Eight more than some number

11. Four less than some number

12. One-third of some number

13. Six more than eight times some number

14. The difference of two numbers

15. Fifty-nine percent of some number

16. Two hundred less than the product of two numbers

17. The sum of two numbers

Answers

9. $x - 8$ **10.** $y + 8$, or $8 + y$ **11.** $m - 4$
12. $\frac{1}{3} \cdot p$, or $\frac{p}{3}$ **13.** $8x + 6$, or $6 + 8x$
14. $a - b$ **15.** $59\%x$, or $0.59x$ **16.** $xy - 200$
17. $p + q$

1.1 Exercise Set

For Extra Help
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Reading Check

Classify each expression as an algebraic expression involving either multiplication or division.

RC1. $3/q$

RC2. $3q$

RC3. $3 \cdot q$

RC4. $\dfrac{3}{q}$

a Substitute to find values of the expressions in each of the following applied problems.

1. ***Commuting Time.*** It takes Abigail 24 min less time to commute to work than it does Jayden. Suppose that the variable x stands for the time it takes Jayden to get to work. Then $x - 24$ stands for the time it takes Abigail to get to work. How long does it take Abigail to get to work if it takes Jayden 56 min? 93 min? 105 min?

2. ***Enrollment Costs.*** At Mountain View Community College, it costs \$600 to enroll in the 8 A.M. section of Elementary Algebra. Suppose that the variable n stands for the number of students who enroll. Then $600n$ stands for the total amount of tuition collected for this course. How much is collected if 34 students enroll? 78 students? 250 students?

3. ***Distance Traveled.*** A driver who drives at a constant speed of r miles per hour for t hours will travel a distance of d miles given by $d = rt$ miles. How far will a driver travel at a speed of 65 mph for 4 hr?

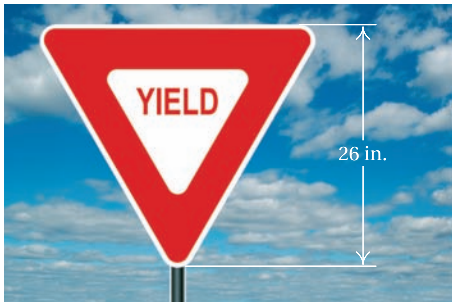
4. ***Simple Interest.*** The simple interest I on a principal of P dollars at interest rate r for time t, in years, is given by $I = Prt$. Find the simple interest on a principal of \$4800 at 3% for 2 years.

5. ***Wireless Internet Sign.*** The U.S. Department of Transportation has designed a new sign that indicates the availability of wireless internet. The square sign measures 24 in. on each side. Find its area.

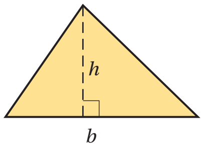
Source: *Manual of Uniform Traffic Control Devices*, U.S. Department of Transportation, 2009

6. ***Yield Sign.*** The U.S. Department of Transportation has designed a new yield sign. Each side of the triangular sign measures 30 in., and the height of the triangle is 26 in. Find its area. The area of a triangle with base b and height h is given by $A = \frac{1}{2}bh$.

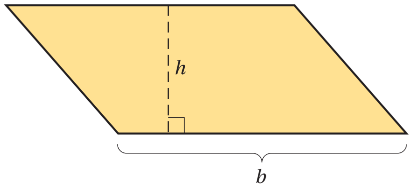
Source: *Manual of Uniform Traffic Control Devices*, U.S. Department of Transportation, 2009



7. ***Area of a Triangle.*** The area A of a triangle with base b and height h is given by $A = \frac{1}{2}bh$. Find the area when $b = 45$ m (meters) and $h = 86$ m.



8. ***Area of a Parallelogram.*** The area A of a parallelogram with base b and height h is given by $A = bh$. Find the area of the parallelogram when the height is 15.4 cm (centimeters) and the base is 6.5 cm.



Evaluate.

9. $8x$, when $x = 7$

10. $6y$, when $y = 7$

11. $\frac{c}{d}$, when $c = 24$ and $d = 3$

12. $\frac{p}{q}$, when $p = 16$ and $q = 2$

13. $\frac{3p}{q}$, when $p = 2$ and $q = 6$

14. $\frac{5y}{z}$, when $y = 15$ and $z = 25$

15. $\frac{x + y}{5}$, when $x = 10$ and $y = 20$

16. $\frac{p + q}{2}$, when $p = 2$ and $q = 16$

17. $\frac{x - y}{8}$, when $x = 20$ and $y = 4$

18. $\frac{m - n}{5}$, when $m = 16$ and $n = 6$

b Translate each phrase to an algebraic expression. Use any letter for the variable(s) unless directed otherwise.

19. Seven more than some number

20. Some number increased by thirteen

21. Twelve less than some number

22. Fourteen less than some number

23. b more than a

24. c more than d

25. x divided by y

26. c divided by h

27. x plus w

28. s added to t

29. m subtracted from n

30. p subtracted from q

31. Twice some number

32. Three times some number

33. Three multiplied by some number

34. The product of eight and some number

35. Six more than four times some number

36. Two more than six times some number

37. Eight less than the product of two numbers

38. The product of two numbers minus seven

39. Five less than twice some number

40. Six less than seven times some number

41. Three times some number plus eleven

42. Some number times 8 plus 5

43. The sum of four times a number plus three times another number

44. Five times a number minus eight times another number

45. Your salary after a 5% salary increase if your salary before the increase was s

46. The price of a chain saw after a 30% reduction if the price before the reduction was P

47. Aubrey drove at a speed of 65 mph for t hours. How far did she travel? (See Exercise 3.)

48. Liam drove his pickup truck at 55 mph for t hours. How far did he travel? (See Exercise 3.)

49. Lisa had \$50 before spending x dollars on pizza. How much money remains?

50. Juan has d dollars before spending \$820 on four new tires for his truck. How much did Juan have after the purchase?

51. Sid's part-time job pays \$12.50 per hour. How much does he earn for working n hours?

52. Meredith pays her babysitter \$10 per hour. What does it cost her to hire the sitter for m hours?

Synthesis

To the student and the instructor: The Synthesis exercises found at the end of most exercise sets challenge students to combine concepts or skills studied in that section or in preceding parts of the text.

Evaluate.

53. $\frac{a - 2b + c}{4b - a}$, when $a = 20$, $b = 10$, and $c = 5$

54. $\frac{x}{y} - \frac{5}{x} + \frac{2}{y}$, when $x = 30$ and $y = 6$

55. $\frac{12 - c}{c + 12b}$, when $b = 1$ and $c = 12$

56. $\frac{2w - 3z}{7y}$, when $w = 5$, $y = 6$, and $z = 1$

The Real Numbers

1.2

OBJECTIVES

a State the integer that corresponds to a real-world situation.

b Graph rational numbers on the number line.

c Convert from fraction notation for a rational number to decimal notation.

d Determine which of two real numbers is greater and indicate which, using $<$ or $>$. Given an inequality like $a > b$, write another inequality with the same meaning. Determine whether an inequality like $-3 \leq 5$ is true or false.

e Find the absolute value of a real number.

A **set** is a collection of objects. For our purposes, we will most often be considering sets of numbers. One way to name a set uses what is called **roster notation**. For example, roster notation for the set containing the numbers 0, 2, and 5 is $\{0, 2, 5\}$.

Sets that are part of other sets are called **subsets**. In this section, we become acquainted with the set of *real numbers* and its various subsets.

Two important subsets of the real numbers are listed below using roster notation.

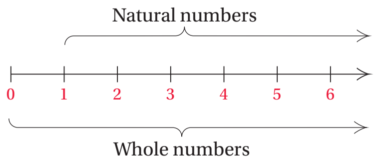
NATURAL NUMBERS

The set of **natural numbers** $= \{1, 2, 3, \ldots\}$. These are the numbers used for counting.

WHOLE NUMBERS

The set of **whole numbers** $= \{0, 1, 2, 3, \ldots\}$. This is the set of natural numbers and 0.

We can represent these sets on the number line. The natural numbers are to the right of zero. The whole numbers are the natural numbers and zero.



We create a new set, called the *integers*, by starting with the whole numbers, 0, 1, 2, 3, and so on. For each natural number 1, 2, 3, and so on, we obtain a new number to the left of zero on the number line:

For the number 1, there will be an *opposite* number -1 (negative 1).

For the number 2, there will be an *opposite* number -2 (negative 2).

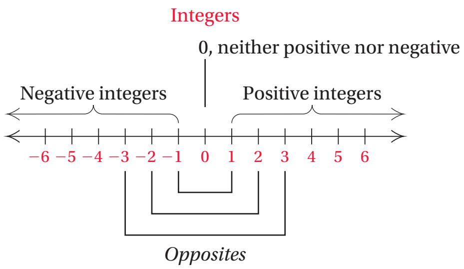
For the number 3, there will be an *opposite* number -3 (negative 3), and so on.

The **integers** consist of the whole numbers and these new numbers.

INTEGERS

The set of **integers** $= \{\ldots, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, \ldots\}$.

We picture the integers on the number line as follows.

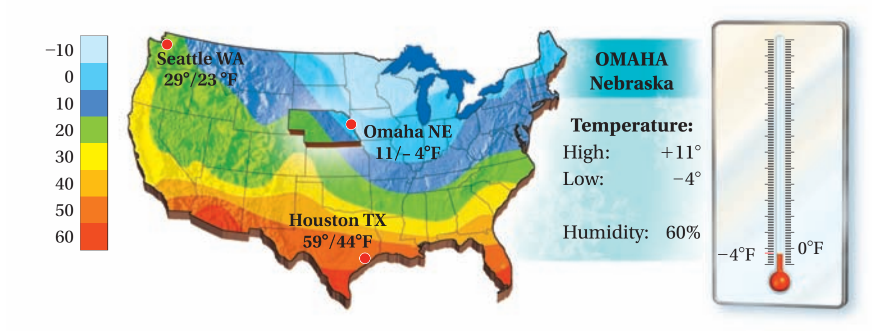


We call the integers to the left of zero **negative integers**. The natural numbers are also called **positive integers**. Zero is neither positive nor negative. We call -1 and 1 **opposites** of each other. Similarly, -2 and 2 are opposites, -3 and 3 are opposites, -100 and 100 are opposites, and 0 is its own opposite. Pairs of opposite numbers like -3 and 3 are the same distance from zero. The integers extend infinitely on the number line to the left and right of zero.

a INTEGERS AND THE REAL WORLD

Integers correspond to many real-world problems and situations. The following examples will help you get ready to translate problem situations that involve integers to mathematical language.

EXAMPLE 1 Tell which integer corresponds to this situation: The temperature is 4 degrees below zero.



The integer -4 corresponds to the situation. The temperature is $-4°$.

EXAMPLE 2 ***Water Level.*** Tell which integer corresponds to this situation: As the water level of the Mississippi River fell during the drought of 2012, barge traffic was restricted, causing a severe decline in shipping volumes. On August 24, the river level at Greenville, Mississippi, was 10 ft below normal.

Source: Rick Jervis, *USA TODAY*, August 24, 2012

The integer -10 corresponds to the drop in water level.

EXAMPLE 3 *Stock Price Change.* Tell which integers correspond to this situation: Hal owns a stock whose price decreased \$16 per share over a recent period. He owns another stock whose price increased \$2 per share over the same period.

The integer -16 corresponds to the decrease in the value of the first stock. The integer 2 represents the increase in the value of the second stock.

Do Exercises 1–5. ▶

b THE RATIONAL NUMBERS

We created the set of integers by obtaining a negative number for each natural number and also including 0. To create a larger number system, called the set of **rational numbers**, we consider quotients of integers with nonzero divisors. The following are some examples of rational numbers:

$$\frac{2}{3},\quad -\frac{2}{3},\quad \frac{7}{1},\quad 4,\quad -3,\quad 0,\quad \frac{23}{-8},\quad 2.4,\quad -0.17,\quad 10\frac{1}{2}.$$

The number $-\frac{2}{3}$ (read "negative two-thirds") can also be named $\frac{-2}{3}$ or $\frac{2}{-3}$; that is,

$$-\frac{a}{b} = \frac{-a}{b} = \frac{a}{-b}.$$

The number 2.4 can be named $\frac{24}{10}$ or $\frac{12}{5}$, and -0.17 can be named $-\frac{17}{100}$. We can describe the set of rational numbers as follows.

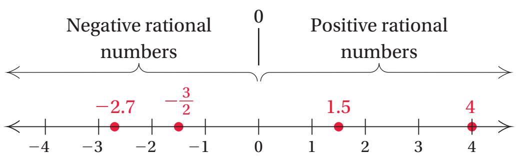
RATIONAL NUMBERS

The set of **rational numbers** $=$ the set of numbers $\frac{a}{b}$,

where a and b are integers and b is not equal to 0 $(b \neq 0)$.

Note that this new set of numbers, the rational numbers, contains the whole numbers, the integers, the arithmetic numbers (also called the non-negative rational numbers), and the negative rational numbers.

We picture the rational numbers on the number line as follows.



To **graph** a number means to find and mark its point on the number line. Some rational numbers are graphed in the preceding figure.

Tell which integers correspond to each situation.

1. *Temperature High and Low.* The highest recorded temperature in Illinois is 117°F on July 14, 1954, in East St. Louis. The lowest recorded temperature in Illinois is 36°F below zero on January 5, 1999, in Congerville.

Source: National Climate Data Center, NESDIS, NOAA, U.S. Department of Commerce (through 2010)

2. *Stock Decrease.* The price of a stock decreased \$3 per share over a recent period.

3. At 10 sec before liftoff, ignition occurs. At 148 sec after liftoff, the first stage is detached from the rocket.

4. The halfback gained 8 yd on first down. The quarterback was sacked for a 5-yd loss on second down.

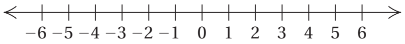
5. A submarine dove 120 ft, rose 50 ft, and then dove 80 ft.

Answers

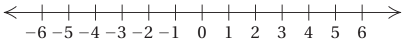
1. 117; −36 **2.** −3 **3.** −10; 148
4. 8; −5 **5.** −120; 50; −80

Graph each number on the number line.

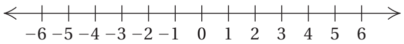
6. $-\dfrac{7}{2}$



7. 1.4

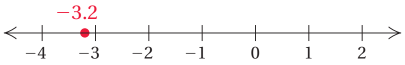


8. $-\dfrac{11}{4}$

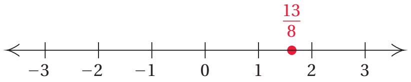


EXAMPLES Graph each number on the number line.

4. -3.2 The graph of -3.2 is $\frac{2}{10}$ of the way from -3 to -4.



5. $\dfrac{13}{8}$ The number $\frac{13}{8}$ can also be named $1\frac{5}{8}$, or 1.625. The graph is $\frac{5}{8}$ of the way from 1 to 2.



Do Exercises 6–8.

C NOTATION FOR RATIONAL NUMBERS

Each rational number can be named using fraction notation or decimal notation.

EXAMPLE 6 Convert to decimal notation: $-\frac{5}{8}$.

We first find decimal notation for $\frac{5}{8}$. Since $\frac{5}{8}$ means $5 \div 8$, we divide.

$$\begin{array}{r} 0.625 \\ 8\overline{)\,5.000} \\ \underline{4\,8} \\ 20 \\ \underline{16} \\ 40 \\ \underline{40} \\ 0 \end{array}$$

Thus, $\frac{5}{8} = 0.625$, so $-\frac{5}{8} = -0.625$.

Decimal notation for $-\frac{5}{8}$ is -0.625. We consider -0.625 to be a **terminating decimal**. Decimal notation for some numbers repeats.

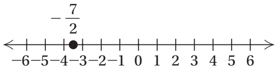
EXAMPLE 7 Convert to decimal notation: $\frac{7}{11}$.

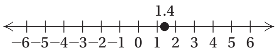
$$\begin{array}{r} 0.6363\ldots \\ 11\overline{)\,7.0000} \\ \underline{6\,6} \\ 40 \\ \underline{33} \\ 70 \\ \underline{66} \\ 40 \\ \underline{33} \\ 7 \end{array}$$

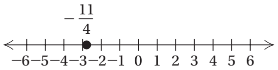
Dividing

We can abbreviate **repeating decimal** notation by writing a bar over the repeating part—in this case, we write $0.\overline{63}$. Thus, $\frac{7}{11} = 0.\overline{63}$.

Answers

6.


7.


8.


Each rational number can be expressed in either terminating decimal notation or repeating decimal notation.

The following are other examples showing how rational numbers can be named using fraction notation or decimal notation:

$$0 = \frac{0}{8}, \quad \frac{27}{100} = 0.27, \quad -8\frac{3}{4} = -8.75, \quad -\frac{13}{6} = -2.1\overline{6}.$$

Do Exercises 9–11. ▶

Find decimal notation.

9. $-\frac{3}{8}$

10. $-\frac{6}{11}$

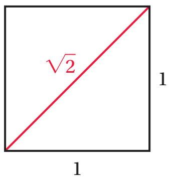
11. $\frac{4}{3}$

d THE REAL NUMBERS AND ORDER

Every rational number has a point on the number line. However, there are some points on the line for which there is no rational number. These points correspond to what are called **irrational numbers**.

What kinds of numbers are irrational? One example is the number π, which is used in finding the area and the circumference of a circle: $A = \pi r^2$ and $C = 2\pi r$.

Another example of an irrational number is the square root of 2, named $\sqrt{2}$. It is the length of the diagonal of a square with sides of length 1. It is also the number that when multiplied by itself gives 2—that is, $\sqrt{2} \cdot \sqrt{2} = 2$. There is no rational number that can be multiplied by itself to get 2. But the following are rational *approximations*:



1.4 is an approximation of $\sqrt{2}$ because $(1.4)^2 = 1.96$;

1.41 is a better approximation because $(1.41)^2 = 1.9881$;

1.4142 is an even better approximation because $(1.4142)^2 = 1.99996164$.

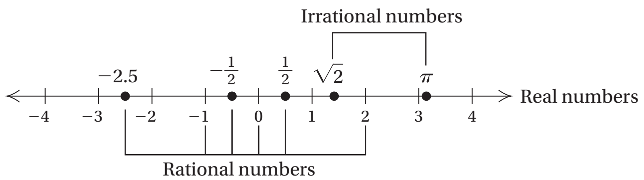
We can find rational approximations for square roots using a calculator.

Decimal notation for rational numbers *either* terminates *or* repeats.

Decimal notation for irrational numbers *neither* terminates *nor* repeats.

Some other examples of irrational numbers are $\sqrt{3}$, $-\sqrt{8}$, $\sqrt{11}$, and 0.121221222122221. . . . Whenever we take the square root of a number that is not a perfect square, we will get an irrational number.

The rational numbers and the irrational numbers together correspond to all the points on the number line and make up what is called the **real-number system**.

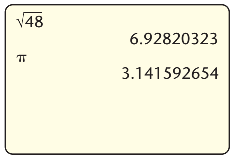


CALCULATOR CORNER

Approximating Square Roots and π Square roots are found by pressing 2ND √. (√ is the second operation associated with the x^2 key.)

To find an approximation for $\sqrt{48}$, we press 2ND √ 4 8 ENTER.

The number π is used widely enough to have its own key. (π is the second operation associated with the ^ key.) To approximate π, we press 2ND π ENTER.



EXERCISES: Approximate.

1. $\sqrt{76}$

2. $\sqrt{317}$

3. $15 \cdot \sqrt{20}$

4. $29 + \sqrt{42}$

5. π

6. $29 \cdot \pi$

7. $\pi \cdot 13^2$

8. $5 \cdot \pi + 8 \cdot \sqrt{237}$

Answers

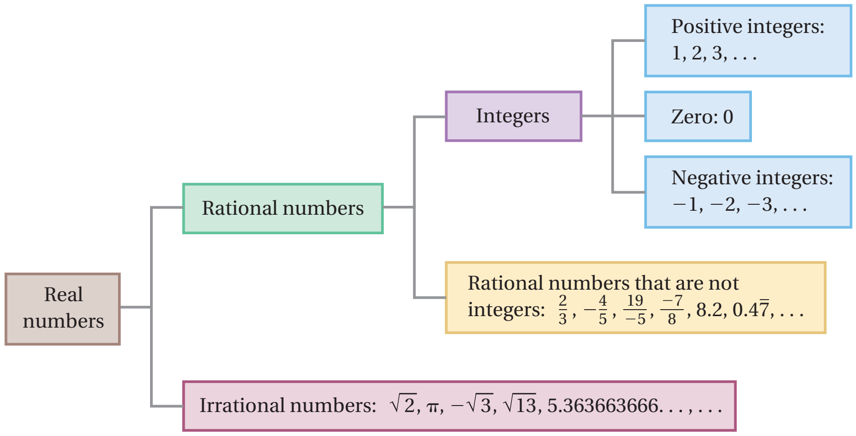
9. -0.375 **10.** $-0.\overline{54}$ **11.** $1.\overline{3}$

REAL NUMBERS

The set of **real numbers** = The set of all numbers corresponding to points on the number line.

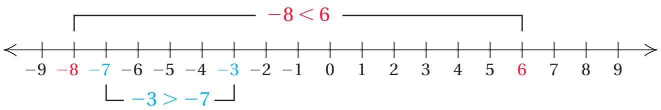
> ### CALCULATOR CORNER
>
> ***Negative Numbers on a Calculator; Converting to Decimal Notation*** We use the opposite key (−) to enter negative numbers on a graphing calculator. Note that this is different from the subtraction key, −.
>
> To convert $-\frac{5}{8}$ to decimal notation, we press (−) 5 ÷ 8 ENTER. The result is −0.625.
>
> ```
> -5/8
>                 -.625
> ```
>
> **EXERCISES:** Convert to decimal notation.
>
> **1.** $-\dfrac{3}{4}$
>
> **2.** $-\dfrac{9}{20}$
>
> **3.** $-\dfrac{1}{8}$
>
> **4.** $-\dfrac{9}{5}$
>
> **5.** $-\dfrac{27}{40}$
>
> **6.** $-\dfrac{11}{16}$
>
> **7.** $-\dfrac{7}{2}$
>
> **8.** $-\dfrac{19}{25}$

The real numbers consist of the rational numbers and the irrational numbers. The following figure shows the relationships among various kinds of numbers.



Order

Real numbers are named in order on the number line, increasing as we move from left to right. For any two numbers on the line, the one on the left is less than the one on the right.



We use the symbol **<** to mean "**is less than**." The sentence $-8 < 6$ means "−8 is less than 6." The symbol **>** means "**is greater than**." The sentence $-3 > -7$ means "−3 is greater than −7." The sentences $-8 < 6$ and $-3 > -7$ are **inequalities**.

EXAMPLES Use either < or > for □ to write a true sentence.

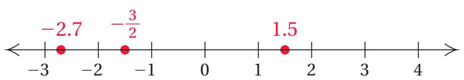
8. 2 □ 9 — Since 2 is to the left of 9, 2 is less than 9, so $2 < 9$.

9. −7 □ 3 — Since −7 is to the left of 3, we have $-7 < 3$.

10. 6 □ −12 — Since 6 is to the right of −12, then $6 > -12$.

11. −18 □ −5 — Since −18 is to the left of −5, we have $-18 < -5$.

12. −2.7 □ $-\frac{3}{2}$ — The answer is $-2.7 < -\frac{3}{2}$.



13. 1.5 □ −2.7 — The answer is $1.5 > -2.7$.

14. 1.38 □ 1.83 — The answer is $1.38 < 1.83$.

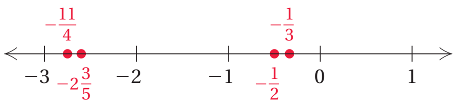
15. $-3.45 \square 1.32$ The answer is $-3.45 < 1.32$.

16. $-4 \square 0$ The answer is $-4 < 0$.

17. $5.8 \square 0$ The answer is $5.8 > 0$.

18. $\frac{5}{8} \square \frac{7}{11}$ We convert to decimal notation: $\frac{5}{8} = 0.625$ and $\frac{7}{11} = 0.6363\ldots$. Thus, $\frac{5}{8} < \frac{7}{11}$.

19. $-\frac{1}{2} \square -\frac{1}{3}$ The answer is $-\frac{1}{2} < -\frac{1}{3}$.



20. $-2\frac{3}{5} \square -\frac{11}{4}$ The answer is $-2\frac{3}{5} > -\frac{11}{4}$.

Do Exercises 12–19. ▶

Note that both $-8 < 6$ and $6 > -8$ are true. Every true inequality yields another true inequality when we interchange the numbers or the variables and reverse the direction of the inequality sign.

ORDER; $>$, $<$

$a < b$ also has the meaning $b > a$.

EXAMPLES Write another inequality with the same meaning.

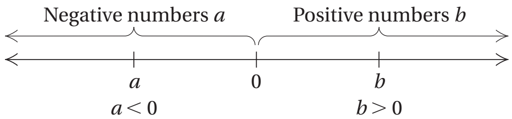
21. $-3 > -8$ The inequality $-8 < -3$ has the same meaning.

22. $a < -5$ The inequality $-5 > a$ has the same meaning.

A helpful mental device is to think of an inequality sign as an "arrow" with the arrowhead pointing to the smaller number.

Do Exercises 20 and 21. ▶

Note that all positive real numbers are greater than zero and all negative real numbers are less than zero.



If b is a positive real number, then $b > 0$.
If a is a negative real number, then $a < 0$.

Use either $<$ or $>$ for $\square$ to write a true sentence.

12. $-3 \square 7$

13. $-8 \square -5$

14. $7 \square -10$

15. $3.1 \square -9.5$

16. $-4.78 \square -5.01$

17. $-\frac{2}{3} \square -\frac{5}{9}$

18. $-\frac{11}{8} \square \frac{23}{15}$

19. $0 \square -9.9$

Write another inequality with the same meaning.

20. $-5 < 7$

21. $x > 4$

Answers

12. $<$ **13.** $<$ **14.** $>$ **15.** $>$ **16.** $>$
17. $<$ **18.** $<$ **19.** $>$ **20.** $7 > -5$
21. $4 < x$

Expressions like $a \leq b$ and $b \geq a$ are also inequalities. We read $\boldsymbol{a \leq b}$ as "***a* is less than or equal to *b***." We read $\boldsymbol{a \geq b}$ as "***a* is greater than or equal to *b***."

Write true or false for each statement.

22. $-4 \leq -6$

23. $7.8 \geq 7.8$

24. $-2 \leq \dfrac{3}{8}$

EXAMPLES Write true or false for each statement.

23. $-3 \leq 5.4$ True since $-3 < 5.4$ is true

24. $-3 \leq -3$ True since $-3 = -3$ is true

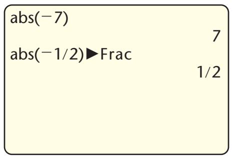
25. $-5 \geq 1\frac{2}{3}$ False since neither $-5 > 1\frac{2}{3}$ nor $-5 = 1\frac{2}{3}$ is true

Do Exercises 22–24.

CALCULATOR CORNER

Absolute Value Finding absolute value is the first item in the Catalog on the T1-84 Plus graphing calculator. To find $|-7|$, we first press 2ND CATALOG ENTER to copy "abs(" to the home screen. (CATALOG is the second operation associated with the 0 numeric key.) Then we press (−) 7) ENTER. The result is 7.

To find $\left|-\frac{1}{2}\right|$ and express the result as a fraction, we press 2ND CATALOG ENTER (−) 1 ÷ 2) MATH 1 ENTER. The result is $\frac{1}{2}$.



EXERCISES: Find the absolute value.

1. $|-5|$ **2.** $|17|$

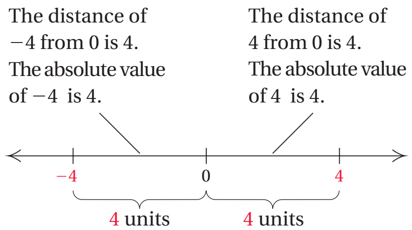
3. $|0|$ **4.** $|6.48|$

5. $|-12.7|$ **6.** $|-0.9|$

7. $\left|-\dfrac{5}{7}\right|$ **8.** $\left|\dfrac{4}{3}\right|$

e ABSOLUTE VALUE

From the number line, we see that numbers like 4 and -4 are the same distance from zero. Distance is always a nonnegative number. We call the distance of a number from zero on the number line the **absolute value** of the number.



ABSOLUTE VALUE

The **absolute value** of a number is its distance from zero on the number line. We use the symbol $|x|$ to represent the absolute value of a number x.

FINDING ABSOLUTE VALUE

a) If a number is negative, its absolute value is its opposite.

b) If a number is positive or zero, its absolute value is the same as the number.

Find the absolute value.

25. $|8|$ **26.** $|-9|$

27. $\left|-\dfrac{2}{3}\right|$ **28.** $|5.6|$

EXAMPLES Find the absolute value.

26. $|-7|$ The distance of -7 from 0 is 7, so $|-7| = 7$.

27. $|12|$ The distance of 12 from 0 is 12, so $|12| = 12$.

28. $|0|$ The distance of 0 from 0 is 0, so $|0| = 0$.

29. $\left|\frac{3}{2}\right| = \frac{3}{2}$

30. $|-2.73| = 2.73$

Do Exercises 25–28.

Answers

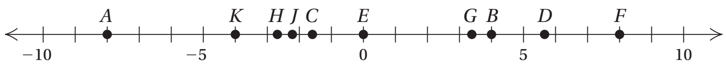
22. False **23.** True **24.** True **25.** 8
26. 9 **27.** $\frac{2}{3}$ **28.** 5.6

1.2 Exercise Set

For Extra Help MyMathLab® MathXL® PRACTICE WATCH READ REVIEW

Reading Check

Use the number line below for Exercises RC1–RC10.



Match each number with its graph.

RC1. $-2\frac{5}{7}$ **RC2.** $\left|\frac{0}{-8}\right|$ **RC3.** -2.25 **RC4.** $\frac{17}{3}$ **RC5.** $|-4|$ **RC6.** $3.\overline{4}$

Write true or false. The letters name numbers on the number line shown above.

RC7. $K < B$ **RC8.** $H < B$ **RC9.** $E < C$ **RC10.** $J > D$

a State the integers that correspond to each situation.

1. On Wednesday, the temperature was 24° above zero. On Thursday, it was 2° below zero.

2. A student deposited her tax refund of \$750 in a savings account. Two weeks later, she withdrew \$125 to pay technology fees.

3. ***Temperature Extremes.*** The highest temperature ever created in a lab is 7,200,000,000,000°F. The lowest temperature ever created is approximately 460°F below zero.

Sources: *Live Science; Guinness Book of World Records*

4. ***Extreme Climate.*** Verkhoyansk, a river port in northeast Siberia, has the most extreme climate on the planet. Its average monthly winter temperature is 58.5°F below zero, and its average monthly summer temperature is 56.5°F.

Source: *Guinness Book of World Records*

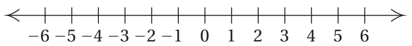
5. ***Empire State Building.*** The Empire State Building has a total height, including the lightning rod at the top, of 1454 ft. The foundation depth is 55 ft below ground level.

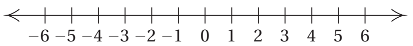
Source: www.empirestatebuildingfacts.com

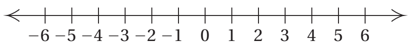
6. ***Shipwreck.*** There are numerous shipwrecks to explore near Bermuda. One of the most frequently visited sites is L'Herminie, a French warship that sank in 1838. This ship is 35 ft below the surface.

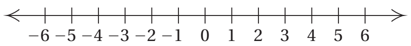
Source: www./10best.com/interests/adventure/scuba-diving-in-pirate-territory/

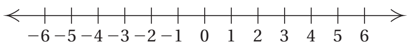
b Graph the number on the number line.

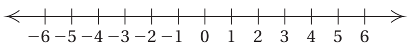
7. $\frac{10}{3}$ 

8. $-\frac{17}{4}$ 

9. -5.2 

10. 4.78 

11. $-4\frac{2}{5}$ 

12. $2\frac{6}{11}$ 

c Convert to decimal notation.

13. $-\frac{7}{8}$

14. $-\frac{3}{16}$

15. $\frac{5}{6}$

16. $\frac{5}{3}$

17. $-\frac{7}{6}$

18. $-\frac{5}{12}$

19. $\frac{2}{3}$

20. $-\frac{11}{9}$

21. $\frac{1}{10}$

22. $\frac{1}{4}$

23. $-\frac{1}{2}$

24. $\frac{9}{8}$

25. $\frac{4}{25}$

26. $-\frac{7}{20}$

d Use either $<$ or $>$ for $\square$ to write a true sentence.

27. $8 \square 0$

28. $3 \square 0$

29. $-8 \square 3$

30. $6 \square -6$

31. $-8 \square 8$

32. $0 \square -9$

33. $-8 \square -5$

34. $-4 \square -3$

35. $-5 \square -11$

36. $-3 \square -4$

37. $2.14 \square 1.24$

38. $-3.3 \square -2.2$