

# Introductory Algebra



Thirteenth Edition

BITTINGER | BEECHER | JOHNSON

EDITION

13

# Introductory Algebra

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# Preface

## Math doesn't change, but students' needs—and the way students learn—do.

With this in mind, *Introductory Algebra*, 13th Edition, continues the Bittinger tradition of objective-based, guided learning, while integrating many updates with the proven pedagogy. These updates are motivated by feedback that we received from students and instructors, as well as our own experience in the classroom. In this edition, our focus is on guided learning and retention: helping each student (and instructor) get the most out of all the available program resources—wherever and whenever they engage with the math.

We believe that student success in math hinges on four key areas: **Foundation**, **Engagement**, **Application**, and **Retention**. In the 13th edition, we have added key new program features (highlighted below, for quick reference) in each area to make it easier for each student to personalize his or her learning experience. In addition, you will recognize many proven features and presentations from the previous edition of the program.

## FOUNDATION

### Studying the Concepts

Students can learn the math concepts by reading the textbook or the eText, participating in class, watching the videos, working in the *MyMathGuide* workbook—or using whatever combination of these course resources works best for them.

In order to understand new math concepts, students must recall and use skills and concepts previously studied. To support student learning, we have integrated two important new features throughout the 13th Edition program:

- **New! Just-in-Time Review** at the beginning of the text and the etext is a set of quick reviews of the key topics from previous courses that are prerequisites for the new material in this course. A note on each Chapter Opener alerts students to the topics they should review for that chapter. In MyLab Math, students will find a concise presentation of each topic in the **Just-in-Time Review Videos**.
- **New! Skill Review**, in nearly every section of the text and the etext, reviews a previously presented skill at the objective level where it is key to learning the new material. This feature offers students two practice exercises with answers. In MyLab Math, new **Skill Review Videos**, created by the Bittinger author team, offer a concise, step-by-step solution for each Skill Review exercise.

**Margin Exercises with Guided Solutions**, with fill-in blanks at key steps in the problem-solving process, appear in nearly every text section and can be assigned in MyLab Math.

**Algebraic–Graphical Connections** in the text draw explicit connections between the algebra and the corresponding graphical visualization.

**Introductory Algebra Video Program**, our comprehensive program of objective-based, interactive videos, can be used hand-in-hand with our *MyMathGuide* workbook. **Interactive Your Turn exercises** in the videos prompt students to solve problems and receive instant feedback. These videos can be accessed at the section, objective, and example levels.

**MyMathGuide** offers students a guided, hands-on learning experience. This objective-based workbook (available in print and in MyLab Math) includes vocabulary, skill, and concept review—as well as problem-solving practice with space for students to fill in the answers and stepped-out solutions to problems, to show (and keep) their work, and to write notes. Students can use *MyMathGuide*, while watching the videos, listening to the instructor’s lecture, or reading the text or the etext, in order to reinforce and self-assess their learning.

**Studying for Success** sections are checklists of study skills designed to ensure that students develop the skills they need to succeed in math, school, and life. They are available at the beginning of selected sections.

## ENGAGEMENT

### Making Connections through Active Exploration

Since understanding the big picture is key to student success, we offer many active learning opportunities for the practice, review, and reinforcement of important concepts and skills.

- New!** **Chapter Opener Applications** with infographics use current data and applications to present the math in context. Each application is related to exercises in the text to help students model, visualize, learn, and retain the math.
- New!** **Student Activities**, included with each chapter, have been developed as multistep, data-based activities for students to apply the math in the context of an authentic application. Student Activities are available in *MyMathGuide* and in MyLab Math.
- New!** **Interactive Animations** can be manipulated by students in MyLab Math through guided and open-ended exploration to further solidify their understanding of important concepts.

**Translating for Success** offers extra practice with the important first step of the process for solving applied problems. **Visualizing for Success** asks students to match an equation or an inequality with its graph by focusing on characteristics of the equation or the inequality and the corresponding attributes of the graph. Both of these activities are available in the text and in MyLab Math.

**Technology Connection** is an optional feature in each chapter that helps students use a calculator to perform calculations and to visualize concepts.

**Learning Catalytics** uses students’ mobile devices for an engagement, assessment, and classroom intelligence system that gives instructors real-time feedback on student learning.

## APPLICATION

### Reinforcing Understanding

As students explore the math, they have frequent opportunities to apply new concepts, practice, self-assess, and reinforce their understanding.

**Margin Exercises**, labeled “Do Exercise . . . ,” give students frequent opportunities to apply concepts just discussed by solving problems that parallel text examples.

**Exercise Sets** in each section offer abundant opportunity for practice and review in the text and in MyLab Math. The Section Exercises are grouped by objective for ease of use, and each set includes the following special exercise types:

- New! Check Your Understanding** with **Reading Check** and **Concept Check** exercises, at the beginning of each exercise set, gives students the opportunity to assess their grasp of the skills and concepts before moving on to the objective-based section exercises. In MyLab Math, many of these exercises use drag & drop functionality.
- Skill Maintenance Exercises** offer a thorough review of the math in the preceding sections of the text.
- Synthesis Exercises** help students develop critical-thinking skills by requiring them to use what they know in combination with content from the current and previous sections.

## RETENTION

### Carrying Success Forward

Because continual practice and review is so important to retention, we have integrated both throughout the program in the text and in MyLab Math.

- New! Skill Builder Adaptive Practice**, available in MyLab Math, offers each student a personalized learning experience. When a student struggles with the assigned homework, Skill Builder exercises offer just-in-time additional adaptive practice. The adaptive engine tracks student performance and delivers to each individual questions that are appropriate for his or her level of understanding. When the system has determined that the student has a high probability of successfully completing the assigned exercise, it suggests that the student return to the assigned homework.

**Mid-Chapter Review** offers an opportunity for active review midway through each chapter. This review offers four types of practice problems:

### Concept Reinforcement, Guided Solutions, Mixed Review, and Understanding Through Discussion and Writing

**Summary and Review** is a comprehensive learning and review section at the end of each chapter. Each of the five sections—**Vocabulary Reinforcement** (fill-in-the-blank), **Concept Reinforcement** (true/false), **Study Guide** (examples with stepped-out solutions paired with similar practice problems), **Review Exercises**, and **Understanding Through Discussion and Writing**—includes references to the section in which the material was covered to facilitate review.

**Chapter Test** offers students the opportunity for comprehensive review and reinforcement prior to taking their instructor’s exam. **Chapter Test Prep Videos** in MyLab Math show step-by-step solutions to the questions on the chapter test.

**Cumulative Review** follows each chapter beginning with Chapter 2. These revisit skills and concepts from all preceding chapters to help students retain previously presented material.

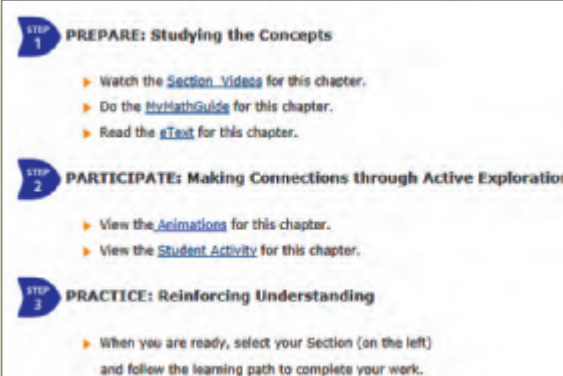
# Resources for Success

**MyLab Math Online Course** for Bittinger, Beecher, and Johnson, *Introductory Algebra*, 13th Edition (access code required)

MyLab™ Math is available to accompany Pearson’s market-leading text offerings. To give students a consistent tone, voice, and teaching method, the pedagogical approach of the text is tightly integrated throughout the accompanying MyLab Math course, making learning the material as seamless as possible.

## UPDATED! Learning Path

Structured, yet flexible, the updated learning path highlights author-created, faculty-vetted content—giving students what they need exactly when they need it. The learning path directs students to resources such as two new types of video: **Just-in-Time Review** (concise presentations of key topics from previous courses) and **Skill Review** (author-created exercises with step-by-step solutions that reinforce previously presented skills), both available in the Multimedia Library and assignable in MyLab Math.



**STEP 1** **PREPARE: Studying the Concepts**

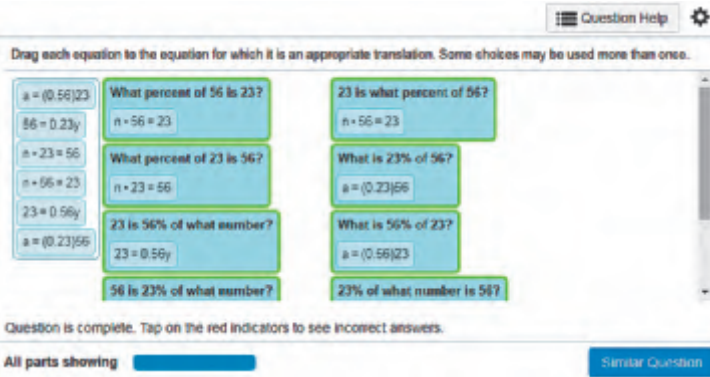
- ▶ Watch the [Section Videos](#) for this chapter.
- ▶ Do the [MyMathGuide](#) for this chapter.
- ▶ Read the [eText](#) for this chapter.

**STEP 2** **PARTICIPATE: Making Connections through Active Exploration**

- ▶ View the [Animations](#) for this chapter.
- ▶ View the [Student Activity](#) for this chapter.

**STEP 3** **PRACTICE: Reinforcing Understanding**

- ▶ When you are ready, select your Section (on the left) and follow the learning path to complete your work.



Drag each equation to the equation for which it is an appropriate translation. Some choices may be used more than once.

Equation choices:

- $a = (0.56)(23)$
- $86 = 0.23y$
- $n + 23 = 56$
- $n + 56 = 23$
- $23 = 0.56y$
- $a = (0.23)(56)$

Word problems:

- What percent of 56 is 23?
- 23 is what percent of 56?
- What percent of 23 is 56?
- What is 23% of 56?
- 23 is 56% of what number?
- What is 56% of 23?
- 56 is 23% of what number?
- 23% of what number is 56?

Question is complete. Tap on the red indicators to see incorrect answers.

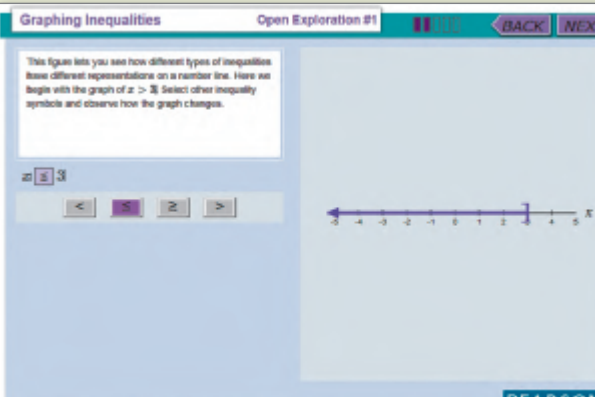
All parts showing ▶ Similar Question

## NEW! Drag-and-Drop Exercises

Drag-and-drop exercises are now available in MyLab Math. This new assignment type allows students to drag answers and values within a problem, providing a new and engaging way to test students’ concept knowledge.

## NEW and UPDATED! Animations

New animations encourage students to learn key concepts through guided and open-ended exploration. Animations are available through the learning path and multimedia library, and they can be assigned within MyLab Math.



**Graphing Inequalities** Open Exploration #1 BACK NEXT

This figure lets you see how different types of inequalities have different representations on a number line. Here we begin with the graph of  $x \geq 3$ . Select other inequality symbols and observe how the graph changes.

$a \geq 3$

< > ≤ ≥ >

Number line:  $x$  from -5 to 5, with a closed circle at 3 and a ray extending to the right.

**PEARSON**

# Resources for Success

## Instructor Resources

Additional resources can be downloaded from [www.pearsonhighered.com](http://www.pearsonhighered.com) or hardcopy resources can be ordered from your sales representative.

### *Annotated Instructor's Edition*

ISBN: 0134718151

- Answers to all text exercises.
- Helpful teaching tips, including suggestions for incorporating Student Activities in the course

### *Instructor's Resource Manual with Tests and Minilectures*

(download only)

ISBN: 0134718313

- Resources designed to help both new and experienced instructors with course preparation and class management.
- Chapter teaching tips and support for media supplements.
- Multiple versions of multiple-choice and free-response chapter tests, as well as final exams.

### *Instructor's Solutions Manual*

(download only)

By Judy Penna

ISBN: 0134718240

The *Instructor's Solutions Manual* includes brief solutions for the even-numbered exercises in the exercise sets and fully worked-out annotated solutions for all the exercises in the Mid-Chapter Reviews, the Summary and Reviews, the Chapter Tests, and the Cumulative Reviews.

### **PowerPoint® Lecture Slides**

(download only)

- Editable slides present key concepts and definitions from the text.
- Available to both instructors and students.
- Fully accessible.

### **TestGen®**

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

## Student Resources

### *Introductory Algebra Lecture Videos*

- Concise, interactive, and objective-based videos.
- View a whole section, choose an objective, or go straight to an example.

### *Chapter Test Prep Videos*

- Step-by-step solutions for every problem in the chapter tests.

### *Just-in-Time Review Videos*

- One video per review topic in the Just-in-Time Review at the beginning of the text.
- View examples and worked-out solutions that parallel the concepts reviewed in each review topic.

### *Skill Review Videos*

Students can review previously presented skills at the objective level with two practice exercises before moving forward in the content. Videos include a step-by-step solution for each exercise.

### *MyMathGuide: Notes, Practice, and Video Path*

ISBN: 013471833X

- Guided, hands-on learning in a workbook format with space for students to show their work and record their notes and questions.
- Highlights key concepts, skills, and definitions; offers quick reviews of key vocabulary terms with practice problems, examples with guided solutions, similar Your Turn exercises, and practice exercises with readiness checks.
- Includes student activities utilizing real data.
- Available in MyLab Math and as a printed manual.

### *Student's Solutions Manual*

ISBN: 0134718178

By Judy Penna

- Includes completely worked-out annotated solutions for odd-numbered exercises in the text, as well as all the exercises in the Mid-Chapter Reviews, the Summary and Reviews, the Chapter Tests, and the Cumulative Reviews.
- Available in MyLab Math and as a printed manual.

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Our goal in writing this textbook was to make mathematics accessible to every student. We want you to be successful in this course and in the mathematics courses you take in the future. Realizing that your time is both valuable and limited, and that you learn in a uniquely individual way, we employ a variety of pedagogical and visual approaches to help you learn in the best and most efficient way possible. We wish you a positive and successful learning experience.

*Marv Bittinger*  
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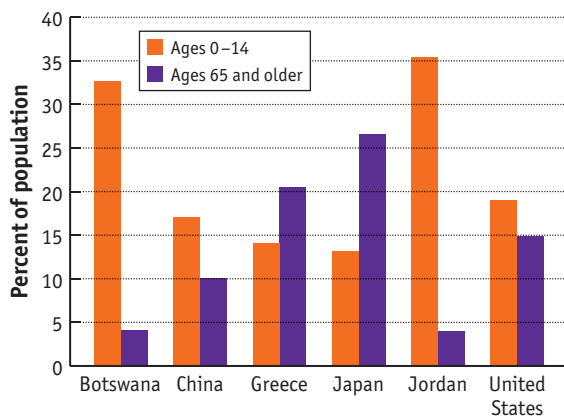
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# Just-in-Time Review



The U.S. population ages 65 and older has continually increased since the baby boomers (those who were born between 1946 and 1964) began turning 65. These increases have both social and economic implications, most notably for Social

## Population Ages 0–14 and Ages 65 and Older



DATA: *The CIA World Factbook, 2017*

Data: U.S. Census Bureau, "An Aging Nation: The Older Population in the United States," by Jennifer M. Ortman, Victoria A. Wilkoff, and Howard Hogan

Security and Medicare. By 2050, the population ages 65 and older is expected to be double that of 2012. Analyzing changes in the percentage of the population in all age groups is important when creating new programs. The graph shows percentages for two age groups in selected countries.

In Example 3 of Just-in-Time 15, we will express as a percentage the portion of the U.S. population ages 65 and older projected for 2060.

- 1 All Factors of a Number
- 2 Prime Factorizations
- 3 Greatest Common Factor
- 4 Least Common Multiple
- 5 Equivalent Expressions and Fraction Notation
- 6 Mixed Numerals
- 7 Simplify Fraction Notation
- 8 Multiply and Divide Fraction Notation
- 9 Add and Subtract Fraction Notation
- 10 Convert from Decimal Notation to Fraction Notation
- 11 Add and Subtract Decimal Notation
- 12 Multiply and Divide Decimal Notation
- 13 Convert from Fraction Notation to Decimal Notation
- 14 Rounding with Decimal Notation
- 15 Convert between Percent Notation and Decimal Notation
- 16 Convert between Percent Notation and Fraction Notation
- 17 Exponential Notation
- 18 Order of Operations

## Just-in-Time Review

### 1

### ALL FACTORS OF A NUMBER

Factoring is a necessary skill for addition and subtraction with fraction notation. Factoring is also an important skill in algebra. The numbers we will be factoring are **natural numbers**:

1, 2, 3, 4, 5, and so on.

To **factor** a number means to express the number as a product. Consider the product  $12 = 3 \cdot 4$ . We say that 3 and 4 are **factors** of 12 and that  $3 \cdot 4$  is a **factorization** of 12. Since  $12 = 1 \cdot 12$  and  $12 = 2 \cdot 6$ , we also know that 1, 12, 2, and 6 are factors of 12 and that  $1 \cdot 12$  and  $2 \cdot 6$  are factorizations of 12.

**EXAMPLE 1** Find all the factors of 77.

We first find some factorizations:

$$77 = 1 \cdot 77,$$

$$77 = 7 \cdot 11.$$

The factors of 77 are 1, 7, 11, and 77.

**EXAMPLE 2** Find all the factors of 150.

We first find some factorizations:

$$150 = 1 \cdot 150,$$

$$150 = 2 \cdot 75,$$

$$150 = 3 \cdot 50,$$

$$150 = 5 \cdot 30,$$

$$150 = 6 \cdot 25,$$

$$150 = 10 \cdot 15.$$

The factors of 150 are 1, 2, 3, 5, 6, 10, 15, 25, 30, 50, 75, and 150.

Do Exercises 1–8. ►

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VIDEO

### EXERCISES

Find all factors of the given number.

1. 20

2. 39

3. 81

4. 47

5. 160

6. 45

7. 28

8. 36

## 2

## PRIME FACTORIZATIONS

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A natural number that has *exactly two different factors*, itself and 1, is called a **prime number**.

**EXAMPLE 1** Which of these numbers are prime? 7, 4, 11, 18, 1

7 is prime. It has exactly two different factors, 1 and 7.

4 is *not* prime. It has three different factors, 1, 2, and 4.

11 is prime. It has exactly two different factors, 1 and 11.

18 is *not* prime. It has factors 1, 2, 3, 6, 9, and 18.

1 is *not* prime. It does not have two *different* factors. ■

In the margin at right is a table of the prime numbers from 2 to 157. These prime numbers will be helpful to you in this text.

If a natural number, other than 1, is not prime, we call it **composite**. Every composite number can be factored into a product of prime numbers. Such a factorization is called a **prime factorization**.

**EXAMPLE 2** Find the prime factorization of 36.

We begin by factoring 36 any way we can. One way is like this:

$$\begin{array}{rcl} 36 & = & 4 \cdot 9 \\ & & \downarrow \quad \downarrow \\ & = & 2 \cdot 2 \cdot 3 \cdot 3. \end{array} \quad \begin{array}{l} \text{The factors 4 and 9 are not prime,} \\ \text{so we factor them.} \end{array}$$

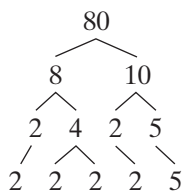
The factors in the last factorization are all prime, so we now have the *prime factorization* of 36. Note that 1 is *not* part of this factorization because it is not prime.

Another way to find the prime factorization of 36 is like this:

$$36 = 2 \cdot 18 = 2 \cdot 3 \cdot 6 = 2 \cdot 3 \cdot 2 \cdot 3. \quad \blacksquare$$

**EXAMPLE 3** Find the prime factorization of 80.

One way to factor 80 is  $8 \cdot 10$ . Here we use a factor tree to find the prime factors of 80.



Each factor in  $2 \cdot 2 \cdot 2 \cdot 2 \cdot 5$  is prime. This is the prime factorization.

Do Exercises 1–8. ►

## EXERCISES

Find the prime factorization of the given number.

- 33
- 121
- 18
- 56
- 120
- 90
- 210
- 91

## A TABLE OF PRIMES

2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97, 101, 103, 107, 109, 113, 127, 131, 137, 139, 149, 151, 157

## Just-in-Time Review

### 3

### GREATEST COMMON FACTOR

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The numbers 20 and 30 have several factors in common, among them 2 and 5. The greatest of the common factors is called the **greatest common factor, GCF**. One way to find the GCF is by making a list of factors of each number.

List all the factors of 20:  $\underline{1}$ ,  $\underline{2}$ , 4,  $\underline{5}$ ,  $\underline{10}$ , and 20.

List all the factors of 30:  $\underline{1}$ , 2, 3,  $\underline{5}$ , 6,  $\underline{10}$ , 15, and 30.

We underline the common factors. The greatest common factor, the GCF, is **10**.

The preceding procedure gives meaning to the notion of a GCF, but the following method, using prime factorizations, is generally faster.

**EXAMPLE 1** Find the GCF of 20 and 30.

We find the prime factorization of each number. Then we draw lines between the common factors.

$$\begin{array}{r} 20 = 2 \cdot 2 \cdot 5 \\ 30 = 2 \cdot 3 \cdot 5 \end{array}$$

The GCF =  $2 \cdot 5 = 10$ .

**EXAMPLE 2** Find the GCF of 54, 90, and 252.

We find the prime factorization of each number. Then we draw lines between the common factors.

$$\begin{array}{r} 54 = 2 \cdot 3 \cdot 3 \cdot 3 \\ 90 = 2 \cdot 3 \cdot 3 \cdot 5 \\ 252 = 2 \cdot 2 \cdot 3 \cdot 3 \cdot 7 \end{array}$$

The GCF =  $2 \cdot 3 \cdot 3 = 18$ .

**EXAMPLE 3** Find the GCF of 30 and 77.

We find the prime factorization of each number.

$$30 = 2 \cdot 3 \cdot 5$$

$$77 = 7 \cdot 11$$

Since there is no common prime factor, the GCF is 1.

Do Exercises 1–10. ►

### EXERCISES

Find the GCF of the given numbers.

- 36, 48
- 13, 52
- 27, 40
- 54, 180
- 18, 66
- 30, 135
- 40, 220
- 14, 42
- 15, 40, 60
- 70, 105, 350

## 4

## LEAST COMMON MULTIPLE

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Two or more numbers always have many multiples in common. From lists of multiples, we can find common multiples. To find the common multiples of 2 and 3, we circle the multiples that appear in both lists of multiples:

$$2, 4, \textcircled{6}, 8, 10, \textcircled{12}, 14, 16, \textcircled{18}, 20, 22, \textcircled{24}, 26, 28, \textcircled{30}, \dots;$$

$$3, \textcircled{6}, 9, \textcircled{12}, 15, \textcircled{18}, 21, \textcircled{24}, 27, \textcircled{30}, \dots$$

The common multiples of 2 and 3 are 6, 12, 18, 24, 30, . . .

The *least*, or smallest, of those common multiples is 6. We abbreviate **least common multiple** as **LCM**.

**EXAMPLE 1** Find the LCM of 9 and 15.

We first look at the factorizations of 9 and 15:

$$9 = 3 \cdot 3, \quad 15 = 3 \cdot 5.$$

Any multiple of 9 must have *two* 3's as factors. Any multiple of 15 must have *one* 3 and *one* 5 as factors. The smallest multiple of 9 and 15 is

$$3 \cdot 3 \cdot 5 = 45.$$

Two 3's; 9 is a factor  
One 3, one 5; 15 is a factor

The LCM must have all the factors of 9 and all the factors of 15, *but the factors are not repeated when they are common to both numbers.* ■

To find the LCM of several numbers using prime factorizations:

- a) Write the prime factorization of each number.
- b) Form the LCM by writing the product of the different factors from step (a), using each factor the greatest number of times that it occurs in any *one* of the factorizations.

**EXAMPLE 2** Find the LCM of 40 and 100.

a) We first find the prime factorizations:

$$40 = 2 \cdot 2 \cdot 2 \cdot 5,$$

$$100 = 2 \cdot 2 \cdot 5 \cdot 5.$$

- b) The different prime factors are 2 and 5. We write 2 as a factor three times (the greatest number of times that it occurs in any *one* factorization). We write 5 as a factor two times (the greatest number of times that it occurs in any *one* factorization).

The LCM is  $2 \cdot 2 \cdot 2 \cdot 5 \cdot 5$ , or 200. ■

(continued)



## Just-in-Time Review

### 4

### LEAST COMMON MULTIPLE (continued)

**EXAMPLE 3** Find the LCM of 27, 90, and 84.

a) We first find the prime factorizations:

$$27 = 3 \cdot 3 \cdot 3,$$

$$90 = 2 \cdot 3 \cdot 3 \cdot 5,$$

$$84 = 2 \cdot 2 \cdot 3 \cdot 7.$$

b) We write 2 as a factor two times, 3 three times, 5 one time, and 7 one time.

The LCM is  $2 \cdot 2 \cdot 3 \cdot 3 \cdot 3 \cdot 5 \cdot 7$ , or 3780.

**EXAMPLE 4** Find the LCM of 7 and 21.

Since 7 is prime, it has no prime factorization. It still, however, must be a factor of the LCM:

$$7 = 7,$$

$$21 = 3 \cdot 7.$$

The LCM is  $7 \cdot 3$ , or 21.

If one number is a factor of another, then the LCM is the larger of the two numbers.

**EXAMPLE 5** Find the LCM of 8 and 9.

We have

$$8 = 2 \cdot 2 \cdot 2,$$

$$9 = 3 \cdot 3.$$

The LCM is  $2 \cdot 2 \cdot 2 \cdot 3 \cdot 3$ , or 72.

If two or more numbers have no common prime factor, then the LCM is the product of the numbers.

Do Exercises 1–10. ►

### EXERCISES

Find the LCM of the given numbers.

1. 24, 27
2. 3, 15
3. 50, 60
4. 13, 23
5. 45, 72
6. 30, 36
7. 12, 28
8. 8, 16, 22
9. 5, 12, 15
10. 24, 35, 45

An example of **fraction notation** for a number is

$$\frac{2}{3} \leftarrow \begin{array}{l} \text{Numerator} \\ \text{Denominator} \end{array}$$

The **whole numbers** consist of the natural numbers and 0:

$$0, 1, 2, 3, 4, 5, \dots$$

The **arithmetic numbers**, also called the **nonnegative rational numbers**, consist of the whole numbers and the fractions, such as  $8$ ,  $\frac{2}{3}$ , and  $\frac{9}{5}$ . All these numbers can be named with fraction notation  $\frac{a}{b}$ , where  $a$  and  $b$  are whole numbers and  $b \neq 0$ .

Note that all whole numbers can be named with fraction notation. For example, we can name the whole number 8 as  $\frac{8}{1}$ . We call 8 and  $\frac{8}{1}$  **equivalent expressions**. Two simple but powerful properties of numbers that allow us to find equivalent expressions are the identity properties of 0 and 1.

#### THE IDENTITY PROPERTY OF 0 (ADDITIVE IDENTITY)

For any number  $a$ ,

$$a + 0 = a.$$

(Adding 0 to any number gives that same number—for example,  $12 + 0 = 12$ .)

#### THE IDENTITY PROPERTY OF 1 (MULTIPLICATIVE IDENTITY)

For any number  $a$ ,

$$a \cdot 1 = a.$$

(Multiplying any number by 1 gives that same number—for example,  $\frac{3}{5} \cdot 1 = \frac{3}{5}$ .)

#### EQUIVALENT EXPRESSIONS FOR 1

For any number  $a$ ,  $a \neq 0$ ,

$$\frac{a}{a} = 1.$$

(For example, some ways to name the number 1 are  $\frac{5}{5}$ ,  $\frac{3}{3}$ , and  $\frac{26}{26}$ .)

#### EXERCISES

Write an equivalent expression with the given denominator.

- $\frac{7}{8}$  (Denominator: 24)
- $\frac{5}{6}$  (Denominator: 48)
- $\frac{5}{4}$  (Denominator: 16)
- $\frac{2}{9}$  (Denominator: 54)
- $\frac{3}{11}$  (Denominator: 77)
- $\frac{13}{16}$  (Denominator: 80)

(continued)

## Just-in-Time Review

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### EQUIVALENT EXPRESSIONS AND FRACTION NOTATION (continued)

**EXAMPLE 1** Write a fraction expression equivalent to  $\frac{2}{3}$  with a denominator of 15.

$$\begin{aligned} \frac{2}{3} &= \frac{2}{3} \cdot 1 && \text{Using the identity property of 1} \\ &= \frac{2}{3} \cdot \frac{5}{5} && \text{Using } \frac{5}{5} \text{ for 1} \\ &= \frac{10}{15} && \text{Multiplying numerators and denominators} \end{aligned}$$

Do Exercises 1–6 on the preceding page. ►

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### MIXED NUMERALS

A mixed numeral like  $2\frac{3}{8}$  represents a sum:  $2 + \frac{3}{8}$ .  
 Whole number  $\uparrow$   $\frac{3}{8}$   $\uparrow$  Fraction less than 1.

To convert  $2\frac{3}{8}$  from a mixed numeral to fraction notation:

- (a) Multiply the whole number 2 by the denominator 8:  $2 \cdot 8 = 16$ .  
 (b) Add the result 16 to the numerator 3:  $16 + 3 = 19$ .  
 (c) Keep the denominator 8.

$$\begin{array}{c} \text{(b)} \rightarrow \frac{3}{8} \\ \frac{2}{8} = \frac{19}{8} \leftarrow \text{(c)} \\ \text{(a)} \leftarrow \end{array}$$

**EXAMPLE 1** Convert to fraction notation.

$$6\frac{2}{3} = \frac{20}{3} \quad 6 \cdot 3 = 18, 18 + 2 = 20$$

To convert from fraction notation to a mixed numeral, divide.

$$\begin{array}{r} \frac{13}{5} \\ 5 \overline{)13} \\ \underline{10} \\ 3 \end{array}$$

The divisor is 5, the quotient is 2, and the remainder is 3.  $2\frac{3}{5}$

**EXAMPLE 2** Convert to a mixed numeral.

$$\frac{69}{10} = 6\frac{9}{10}$$

$$\begin{array}{r} 6 \\ 10 \overline{)69} \\ \underline{60} \\ 9 \end{array}$$

Do Exercises 1–10. ►

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### EXERCISES

Convert to fraction notation.

1.  $5\frac{2}{3}$

2.  $9\frac{1}{10}$

3.  $30\frac{4}{5}$

4.  $1\frac{5}{8}$

5.  $66\frac{2}{3}$

Convert to a mixed numeral.

6.  $\frac{18}{5}$

7.  $\frac{29}{6}$

8.  $\frac{57}{10}$

9.  $\frac{40}{3}$

10.  $\frac{757}{100}$

We know that  $\frac{1}{2}$ ,  $\frac{2}{4}$ ,  $\frac{4}{8}$ , and so on, all name the same number. Any arithmetic number can be named in many ways. The **simplest fraction notation** is the notation that has the smallest numerator and denominator. We call the process of finding the simplest fraction notation **simplifying**. When simplifying fractions, we remove factors of 1.

**EXAMPLE 1** Simplify:  $\frac{10}{15}$ .

$$\begin{aligned}\frac{10}{15} &= \frac{2 \cdot 5}{3 \cdot 5} && \text{Factoring the numerator and the denominator.} \\ & && \text{In this case, each is the prime factorization.} \\ &= \frac{2 \cdot \cancel{5}}{3 \cdot \cancel{5}} && \text{Factoring the fraction expression} \\ &= \frac{2}{3} \cdot 1 && \frac{5}{5} = 1 \\ &= \frac{2}{3} && \text{Using the identity property of 1} \\ & && \text{(removing a factor of 1)}\end{aligned}$$

**EXAMPLE 2** Simplify:  $\frac{36}{24}$ .

$$\frac{36}{24} = \frac{2 \cdot 3 \cdot 2 \cdot 3}{2 \cdot 2 \cdot 3 \cdot 2} = \frac{2 \cdot 3 \cdot 2}{2 \cdot 3 \cdot 2} \cdot \frac{3}{2} = 1 \cdot \frac{3}{2} = \frac{3}{2}$$

### Canceling

Canceling is a shortcut that you may have used to remove a factor of 1 when working with fraction notation. With *great* concern, we mention it as a possible way to speed up your work. You should use canceling only when removing common factors in numerators and denominators. Each common factor allows us to remove a factor of 1 in a product.

**Canceling cannot be done when adding.** Example 2 might have been done faster as follows:

$$\frac{36}{24} = \frac{2 \cdot \cancel{3} \cdot 2 \cdot 3}{2 \cdot 2 \cdot \cancel{3} \cdot 2} = \frac{3}{2}, \quad \text{or} \quad \frac{36}{24} = \frac{3 \cdot \cancel{12}}{2 \cdot \cancel{12}} = \frac{3}{2}, \quad \text{or} \quad \frac{\overset{3}{\cancel{36}}}{\underset{\frac{12}{2}}{\cancel{24}}} = \frac{3}{2}.$$

**EXAMPLE 3** Simplify:  $\frac{18}{72}$ .

$$\frac{18}{72} = \frac{2 \cdot \cancel{9}}{8 \cdot \cancel{9}} = \frac{2}{8} = \frac{2 \cdot 1}{2 \cdot 4} = \frac{1}{4}, \quad \text{or} \quad \frac{18}{72} = \frac{1 \cdot \cancel{18}}{4 \cdot \cancel{18}} = \frac{1}{4}$$

Do Exercises 1–12. ►

### EXERCISES

Simplify.

1.  $\frac{18}{27}$

2.  $\frac{49}{56}$

3.  $\frac{30}{72}$

4.  $\frac{240}{600}$

5.  $\frac{56}{14}$

6.  $\frac{45}{60}$

7.  $\frac{216}{18}$

8.  $\frac{6}{42}$

9.  $\frac{33}{81}$

10.  $\frac{2600}{1400}$

11.  $\frac{84}{126}$

12.  $\frac{325}{625}$