



# Fractions, Decimals, and Percents: The Fluency Foundation

Four focused lessons, worked examples, a mistake clinic, and 60 practice problems with full explanations.

## In this booster

**01.1** Understanding and Comparing Fractions

**01.2** Adding, Subtracting, Multiplying, and Dividing Fractions

**01.3** Decimals and Place Value

**01.4** Percents in Real Life

Every section teaches the idea, walks through the most common problem types, flags the traps students fall into, and ends with fifteen practice problems. Full answers and explanations are at the back.

## 01.1 Understanding and Comparing Fractions

Learn what a fraction really means, how to make equivalent fractions, simplify, compare, convert mixed numbers, and place fractions on a number line with confidence.

### Why This Matters

Fractions show up every time you share a pizza, read a measuring cup, or compare two sale prices. They are also the doorway to ratios, percents, algebra, and almost every science class. Students usually get stuck for one reason: they treat the top and bottom of a fraction like two separate whole numbers instead of one number that describes a part of a whole.

The most common struggles are thinking that a bigger denominator means a bigger fraction (it does not), forgetting to change both the numerator and denominator when making an equivalent fraction, and mixing up mixed numbers and improper fractions. This section fixes all three by building a picture in your head first and then adding the rules.

### Core Ideas

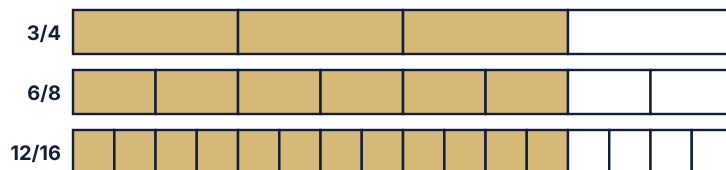
A **fraction**  $\frac{a}{b}$  names  $a$  equal pieces out of a whole that has been cut into  $b$  equal pieces. The bottom number (the **denominator**) tells you how big each piece is. The top number (the **numerator**) tells you how many pieces you have. When the whole is cut into more pieces, each piece gets smaller, so  $\frac{1}{8}$  is smaller than  $\frac{1}{4}$ .

### Equivalent Fractions

Two fractions are **equivalent** when they name the same amount. You can make an equivalent fraction by multiplying or dividing the numerator and the denominator by the same nonzero number:

$$\frac{a}{b} = \frac{a \cdot n}{b \cdot n} = \frac{a \div n}{b \div n}$$

You are multiplying by  $\frac{n}{n} = 1$ , so the value never changes.



The same amount of the bar is shaded in every row, so  $\frac{3}{4}$ ,  $\frac{6}{8}$ , and  $\frac{12}{16}$  are equivalent fractions.

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**Simplifying** a fraction means dividing the top and bottom by their **greatest common factor** (GCF). A fraction is in **simplest form** when the only number that divides both parts is 1. For  $\frac{18}{30}$ , the GCF is 6, so  $\frac{18}{30} = \frac{3}{5}$ . If you cannot spot the GCF, divide by any common factor you can see and repeat until nothing more divides both.

Comparing Fractions

Same denominator: the fraction with the larger numerator is larger.

Same numerator: the fraction with the smaller denominator is larger, because its pieces are bigger.

Different parts: rewrite both with a common denominator (the least common multiple of the denominators is the neatest choice), then compare numerators. You can also compare each fraction to a benchmark such as  $\frac{1}{2}$  or 1.

A **mixed number** such as  $3\frac{2}{5}$  is a whole number plus a fraction. An **improper fraction** such as  $\frac{17}{5}$  has a numerator that is at least as big as its denominator. To change a mixed number to an improper fraction, multiply the whole number by the denominator, add the numerator, and keep the denominator:  $3 \cdot 5 + 2 = 17$ . To go back, divide the numerator by the denominator: the quotient is the whole number and the remainder is the new numerator.

| Fraction        | Benchmark                        | Why                                      |
|-----------------|----------------------------------|------------------------------------------|
| $\frac{3}{8}$   | less than $\frac{1}{2}$          | half of 8 is 4, and 3 is short of 4      |
| $\frac{5}{9}$   | a little more than $\frac{1}{2}$ | half of 9 is 4.5, and 5 is more than 4.5 |
| $\frac{11}{12}$ | almost 1                         | only $\frac{1}{12}$ is missing           |
| $\frac{7}{4}$   | between 1 and 2                  | $\frac{4}{4} = 1$ and $\frac{8}{4} = 2$  |

On a **number line**, the distance from 0 to 1 is cut into equal pieces. The denominator tells you how many pieces, and the numerator tells you how many steps to take from 0. A fraction farther to the right is always the larger one, so a number line is a quick way to check any comparison. Improper fractions and mixed numbers live to the right of 1.



$\frac{1}{2}$  is halfway between 0 and 1.  $\frac{7}{4}$  is three quarters of the way from 1 to 2.  $2\frac{1}{3}$  is one third of the way from 2 to 3.

**A fraction is also a division problem.** The fraction bar means "divided by," so  $\frac{3}{4}$  is the same as  $3 \div 4$ . This is why a fraction like  $\frac{9}{3}$  equals 3, and why  $\frac{7}{4}$  is more than 1: you are splitting 7 things into groups of 4, and there is more than one group's worth. A fraction whose numerator equals its denominator, such as  $\frac{5}{5}$ , is exactly 1.

**A fast way to compare: cross multiplication.** To compare  $\frac{a}{b}$  and  $\frac{c}{d}$ , multiply diagonally. Compute  $a \cdot d$  and  $b \cdot c$ . The fraction on the side of the larger product is the larger fraction. For  $\frac{5}{8}$  and  $\frac{7}{12}$ ,  $5 \cdot 12 = 60$  and  $8 \cdot 7 = 56$ . Since  $60 > 56$ ,  $\frac{5}{8}$  is larger. This is just the common-denominator method in disguise (the common denominator is  $b \cdot d$ ), but it is quick and easy to do in your head.

| Fraction      | Equivalent fractions                                         |
|---------------|--------------------------------------------------------------|
| $\frac{1}{2}$ | $\frac{2}{4} = \frac{3}{6} = \frac{4}{8} = \frac{5}{10}$     |
| $\frac{1}{3}$ | $\frac{2}{6} = \frac{3}{9} = \frac{4}{12} = \frac{5}{15}$    |
| $\frac{2}{5}$ | $\frac{4}{10} = \frac{6}{15} = \frac{8}{20} = \frac{10}{25}$ |
| $\frac{3}{4}$ | $\frac{6}{8} = \frac{9}{12} = \frac{12}{16} = \frac{15}{20}$ |

Learning a few of these families by heart makes fractions feel friendly. When you see  $\frac{6}{15}$  on a worksheet, you should recognize it as a member of the  $\frac{2}{5}$  family. Between any two fractions there are always more fractions, which you can find by writing both with a bigger common denominator, such as multiplying the top and bottom of each by 10.

Worked Examples

EXAMPLE 1: EQUIVALENT FRACTIONS

Fill in the blank:  $\frac{3}{4} = \frac{\quad}{20}$ .

SOLUTION

Compare the denominators:  $4 \rightarrow 20$ . Since  $4 \cdot 5 = 20$ , the multiplier is 5.

Multiply the numerator by the same number:  $3 \cdot 5 = 15$ .

So  $\frac{3}{4} = \frac{15}{20}$ .

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**EXAMPLE 2: SIMPLEST FORM**

Write  $\frac{42}{56}$  in simplest form.

**SOLUTION**

Both numbers are even, so divide by 2:  $\frac{21}{28}$ .

Both 21 and 28 are multiples of 7, so divide by 7:  $\frac{3}{4}$ .

Nothing but 1 divides both 3 and 4, so the answer is  $\frac{3}{4}$ . (Using the GCF of 14 does it in one step.)

**EXAMPLE 3: COMPARING WITH DIFFERENT DENOMINATORS**

Which is larger,  $\frac{5}{8}$  or  $\frac{7}{12}$ ?

**SOLUTION**

The least common multiple of 8 and 12 is 24.

$$\frac{5}{8} = \frac{5 \cdot 3}{8 \cdot 3} = \frac{15}{24} \text{ and } \frac{7}{12} = \frac{7 \cdot 2}{12 \cdot 2} = \frac{14}{24}.$$

Since  $15 > 14$ ,  $\frac{5}{8}$  is larger. The difference is only  $\frac{1}{24}$ , which is why a quick guess can go wrong.

**EXAMPLE 4: MIXED NUMBERS**

(a) Write  $3\frac{2}{5}$  as an improper fraction. (b) Write  $\frac{29}{6}$  as a mixed number.

**SOLUTION**

(a) Multiply the whole number by the denominator:  $3 \cdot 5 = 15$ . Add the numerator:  $15 + 2 = 17$ . Keep the denominator:  $\frac{17}{5}$ .

(b) Divide:  $29 \div 6 = 4$  remainder 5. The quotient 4 is the whole number and the remainder 5 is the new numerator, so  $\frac{29}{6} = 4\frac{5}{6}$ .

Check (b):  $4 \cdot 6 + 5 = 29$ . Yes.

**EXAMPLE 5: ORDERING FOUR FRACTIONS**

Put  $\frac{2}{3}$ ,  $\frac{3}{5}$ ,  $\frac{7}{10}$ , and  $\frac{5}{8}$  in order from least to greatest.

**SOLUTION**

The least common multiple of 3, 5, 10, and 8 is 120.

$$\frac{2}{3} = \frac{80}{120}, \frac{3}{5} = \frac{72}{120}, \frac{7}{10} = \frac{84}{120}, \frac{5}{8} = \frac{75}{120}.$$

Order the numerators:  $72 < 75 < 80 < 84$ .

So the order is  $\frac{3}{5}$ ,  $\frac{5}{8}$ ,  $\frac{2}{3}$ ,  $\frac{7}{10}$ .

**EXAMPLE 6: COMPARING MIXED NUMBERS**

Which is greater,  $4\frac{3}{5}$  or  $4\frac{5}{8}$ ? Then compare  $5\frac{1}{6}$  and  $4\frac{9}{10}$ .

**SOLUTION**

Both of the first pair have the whole number 4, so compare the fraction parts only:  $\frac{3}{5}$  and  $\frac{5}{8}$ .

Common denominator 40:  $\frac{3}{5} = \frac{24}{40}$  and  $\frac{5}{8} = \frac{25}{40}$ . Since  $25 > 24$ ,  $4\frac{5}{8}$  is greater.

For the second pair, the whole numbers are different, so no fraction work is needed.  $5 > 4$ , so  $5\frac{1}{6}$  is greater than  $4\frac{9}{10}$ , even though  $\frac{9}{10}$  is bigger than  $\frac{1}{6}$ .

Rule of thumb: compare whole numbers first, and only compare the fractions if the whole numbers tie.



Zoomed in between 0.5 and 0.8, the four fractions from Example 5 sit in order from left to right.

**Coach's Playbook**

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- 1 **Picture it first.** Sketch a quick bar or number line. If your answer does not match the picture, something went wrong.
  - 2 **Find the benchmark.** Ask whether each fraction is less than, near, or more than  $\frac{1}{2}$  and 1. This settles many comparisons without any work.
  - 3 **Use a common denominator.** When two fractions are close, rewrite both with the same denominator and compare the numerators.
  - 4 **Simplify last, and check.** After simplifying, multiply back. If you get the original fraction, you are done.
  - 5 **Cross-check with the number line.** The larger fraction must sit to the right. If it does not, recheck your multiplication.
- ◆ **Quick test for equivalence:**  $\frac{a}{b} = \frac{c}{d}$  exactly when  $a \cdot d = b \cdot c$ . For example  $5 \cdot 63 = 315$  and  $9 \cdot 35 = 315$ , so  $\frac{5}{9} = \frac{35}{63}$ .
  - ◆ **Divisibility tips for simplifying:** even numbers divide by 2, digit sums divisible by 3 mean divisible by 3, endings of 0 or 5 divide by 5.

### Common traps

(1) Adding the same number to the top and bottom to make an equivalent fraction. You must multiply or divide, not add.  
 (2) Believing  $\frac{1}{8}$  is bigger than  $\frac{1}{4}$  because 8 is bigger than 4. (3) Stopping early when simplifying, for example leaving  $\frac{18}{24}$  as  $\frac{9}{12}$ . (4) Writing a mixed number as an improper fraction by multiplying the whole number by the numerator instead of the denominator.

## Mistake Clinic

### Spot the error

**Problem:** Fill in the blank:  $\frac{2}{5} = \frac{?}{15}$ . **Student's work:** The denominator went from 5 to 15, which is 10 more, so the numerator goes from 2 to 12. Answer:  $\frac{12}{15}$ . **What went wrong:** The student added 10 instead of multiplying. Adding the same number to the top and bottom changes the value. Here  $\frac{12}{15} = \frac{4}{5}$ , which is not  $\frac{2}{5}$ . **Correct solution:** The denominator was multiplied by 3 ( $5 \cdot 3 = 15$ ), so multiply the numerator by 3 too:  $2 \cdot 3 = 6$ . The answer is  $\frac{6}{15}$ .

### Spot the error

**Problem:** Which is larger,  $\frac{3}{7}$  or  $\frac{3}{5}$ ? **Student's work:** 7 is bigger than 5, so  $\frac{3}{7}$  is larger. **What went wrong:** The student compared the denominators as if a bigger denominator means a bigger fraction. When the numerators match, bigger denominators mean smaller pieces. **Correct solution:** Sevenths are smaller than fifths, so 3 sevenths is less than 3 fifths. Check with a common denominator of 35:  $\frac{15}{35}$  versus  $\frac{21}{35}$ . So  $\frac{3}{5}$  is larger.

### Spot the error

**Problem:** Write  $4\frac{2}{3}$  as an improper fraction. **Student's work:**  $4 \cdot 2 = 8$ , then  $8 + 3 = 11$ , so the answer is  $\frac{11}{3}$ . **What went wrong:** The student multiplied the whole number by the numerator instead of by the denominator. The denominator tells the size of the pieces, and that is what the wholes are converted to. **Correct solution:** Multiply the whole number by the denominator:  $4 \cdot 3 = 12$ . Add the numerator:  $12 + 2 = 14$ . Keep the denominator:  $\frac{14}{3}$ . Check:  $14 \div 3 = 4$  remainder 2.

### Real-World Connection

A measuring cup shows  $\frac{1}{4}$ ,  $\frac{1}{3}$ , and  $\frac{1}{2}$  cup. A recipe that calls for  $\frac{3}{8}$  cup needs you to know that it is more than  $\frac{1}{3}$  cup ( $\frac{9}{24}$  versus  $\frac{8}{24}$ ) but less than  $\frac{1}{2}$  cup.

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**Challenge Corner**

Find a fraction with denominator 12 that lies strictly between  $\frac{2}{5}$  and  $\frac{1}{2}$ . **Solution:** Use the common denominator 60.  $\frac{2}{5} = \frac{24}{60}$  and  $\frac{1}{2} = \frac{30}{60}$ . A fraction  $\frac{n}{12}$  equals  $\frac{5n}{60}$ , so we need  $24 < 5n < 30$ . The only whole number  $n$  that works is  $n = 5$  (since  $5 \cdot 5 = 25$ ). The answer is  $\frac{5}{12}$ . Check:  $\frac{5}{12} \approx 0.417$ , which is between 0.4 and 0.5.

**Practice****PRACTICE Understanding and Comparing Fractions**

Show your work on paper. Use a calculator only when a problem says so, or if it is allowed at your level.

- Which fraction is equivalent to  $\frac{5}{9}$ ?  
(A)  $\frac{7}{11}$  (B)  $\frac{10}{18}$  (C)  $\frac{5}{18}$  (D)  $\frac{15}{36}$
- What is  $\frac{54}{90}$  in simplest form?  
(A)  $\frac{27}{45}$  (B)  $\frac{9}{15}$  (C)  $\frac{3}{5}$  (D)  $\frac{6}{10}$
- Which fraction is the greatest?  
(A)  $\frac{4}{5}$  (B)  $\frac{7}{9}$  (C)  $\frac{3}{4}$  (D)  $\frac{11}{15}$
- Write  $5\frac{3}{8}$  as an improper fraction.  
(A)  $\frac{15}{8}$  (B)  $\frac{53}{8}$  (C)  $\frac{38}{8}$  (D)  $\frac{43}{8}$
- Which fraction is between  $\frac{1}{3}$  and  $\frac{1}{2}$ ?  
(A)  $\frac{3}{10}$  (B)  $\frac{2}{5}$  (C)  $\frac{5}{8}$  (D)  $\frac{1}{6}$
- Maya ate  $\frac{3}{8}$  of a pizza and Leo ate  $\frac{5}{12}$  of an identical pizza. Who ate more, and by how much?  
(A) Maya, by  $\frac{1}{24}$  (B) Maya, by  $\frac{1}{4}$  (C) Leo, by  $\frac{1}{24}$   
(D) Leo, by  $\frac{2}{4}$
- Which list is in order from least to greatest?  
(A)  $\frac{2}{3}$ ,  $\frac{5}{8}$ ,  $\frac{3}{5}$ ,  $\frac{1}{2}$  (B)  $\frac{3}{5}$ ,  $\frac{1}{2}$ ,  $\frac{5}{8}$ ,  $\frac{2}{3}$  (C)  $\frac{1}{2}$ ,  $\frac{5}{8}$ ,  $\frac{3}{5}$ ,  $\frac{2}{3}$   
(D)  $\frac{1}{2}$ ,  $\frac{3}{5}$ ,  $\frac{5}{8}$ ,  $\frac{2}{3}$
- Which mixed number is equal to  $\frac{47}{9}$ ?  
(A)  $5\frac{2}{9}$  (B)  $4\frac{7}{9}$  (C)  $5\frac{7}{9}$  (D)  $4\frac{2}{9}$
- Which fraction is closest to 1?  
(A)  $\frac{7}{8}$  (B)  $\frac{9}{10}$  (C)  $\frac{11}{12}$  (D)  $\frac{4}{5}$
- Write  $\frac{126}{84}$  as a mixed number in simplest form.
- Find the value of  $n$  that makes  $\frac{5}{n} = \frac{35}{63}$  true.
- Order from least to greatest:  $\frac{3}{4}$ ,  $\frac{5}{7}$ ,  $\frac{7}{10}$ ,  $\frac{2}{3}$ .
- How many fractions with denominator 20 are strictly between  $\frac{1}{4}$  and  $\frac{3}{4}$ ? (Do not simplify them; count every numerator that works.)
- Write  $\frac{360}{840}$  in simplest form.
- What is the smallest whole number  $n$  for which  $\frac{5}{n}$  is less than  $\frac{1}{4}$ ?

**01.2 Adding, Subtracting, Multiplying, and Dividing Fractions**

Master the four fraction operations: common denominators for adding and subtracting, straight-across multiplying, reciprocals for dividing, mixed-number strategies, and how to set up fraction word problems.

**Why This Matters**

Once you can work with fractions, you can double a recipe, split a bill, measure lumber, and figure out how much of a project is finished. Fraction operations are also the training ground for algebra: the same ideas about common denominators and reciprocals return when you simplify expressions and solve equations with letters in them.

Students get stuck because the four operations follow four different rules, and it is easy to mix them up. The two big mistakes are adding the denominators together (which is never correct) and forgetting to flip the second fraction when dividing. Another common problem is working with mixed numbers without changing them first. Let us build a clear rule for each operation and a quick check for every answer.

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Core Ideas

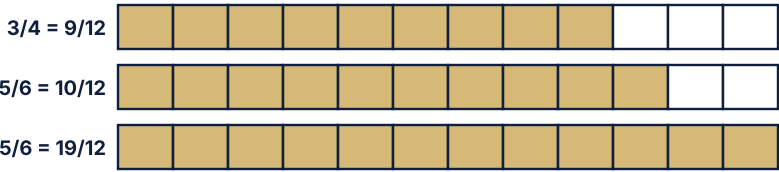
**Adding and subtracting** only works when the pieces are the same size. That is why you need a common denominator. You change the denominators to match, then add or subtract the numerators and keep the denominator the same. The denominator names the size of the piece, and the size does not change when you combine pieces.

Adding and Subtracting Fractions

Find a common denominator (the least common multiple is neatest), rewrite each fraction, then combine the numerators:

$$\frac{a}{c} \pm \frac{b}{c} = \frac{a \pm b}{c}$$

Never add or subtract the denominators. Simplify and, if needed, change an improper fraction to a mixed number at the end.



Both fractions are cut into twelfths so the pieces match. 9 twelfths plus 10 twelfths is 19 twelfths, which is more than one whole bar (the bottom bar is full, with 7 twelfths left over).

**Multiplying** fractions is the easiest operation. A product like  $\frac{2}{3} \cdot \frac{9}{10}$  means " $\frac{2}{3}$  of  $\frac{9}{10}$ ." The word "of" almost always means multiply. You do not need a common denominator.

Multiplying and Dividing Fractions

**Multiply:**

$$\frac{a}{b} \cdot \frac{c}{d} = \frac{a \cdot c}{b \cdot d}$$

Cancel common factors between any numerator and any denominator first to keep the numbers small.

**Divide:** multiply by the **reciprocal** of the second fraction.

$$\frac{a}{b} \div \frac{c}{d} = \frac{a}{b} \cdot \frac{d}{c}$$

The reciprocal of  $\frac{c}{d}$  is  $\frac{d}{c}$ , and the reciprocal of a whole number  $n$  is  $\frac{1}{n}$ .

Why does dividing by a fraction work? The question  $2 \div \frac{1}{4}$  asks "how many quarters fit in 2?" Each whole holds 4 quarters, so 2 wholes hold 8. That is the same as  $2 \cdot 4$ . Dividing by  $\frac{1}{4}$  and multiplying by 4 give the same result.



Counting jumps of 1/4 from 0 to 2 takes 8 jumps, so 2 divided by 1/4 equals 8.

**Mixed numbers.** For multiplying and dividing, always change mixed numbers to improper fractions first. Multiplying the whole parts and the fraction parts separately gives a wrong answer. For adding and subtracting you may keep the mixed form, but if you need to borrow (for example  $5\frac{1}{3} - 2\frac{3}{4}$ ), converting to improper fractions is safer.

| Operation       | Common denominator needed? | What to do                                        |
|-----------------|----------------------------|---------------------------------------------------|
| Add or subtract | Yes                        | Match denominators, combine numerators            |
| Multiply        | No                         | Top times top, bottom times bottom                |
| Divide          | No                         | Multiply by the reciprocal of the second fraction |

**Finding a common denominator.** List the multiples of each denominator until you find one that appears in both lists. For  $\frac{1}{6}$  and  $\frac{1}{15}$ : multiples of 6 are 6, 12, 18, 24, 30, and multiples of 15 are 15, 30. The first match is 30, so the least common multiple is 30. You can always use the product of the denominators (here  $6 \cdot 15 = 90$ ), but the answer will need more simplifying at the end.

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| Denominators | Least common multiple | Why                                                 |
|--------------|-----------------------|-----------------------------------------------------|
| 4 and 6      | 12                    | multiples of 6: 6, 12; 12 is also a multiple of 4   |
| 8 and 12     | 24                    | multiples of 12: 12, 24; 24 is also a multiple of 8 |
| 5 and 7      | 35                    | no shared factor, so multiply them                  |
| 3 and 9      | 9                     | 9 is already a multiple of 3                        |

**Cancel before you multiply.** In  $\frac{4}{9} \cdot \frac{3}{8}$ , the 4 on top and the 8 on the bottom share a factor of 4, and the 3 on top and the 9 on the bottom share a factor of 3. Canceling gives  $\frac{1}{3} \cdot \frac{1}{2} = \frac{1}{6}$  without ever writing a large number. Canceling is allowed between any numerator and any denominator because you are really just simplifying the final fraction early. You may NOT cancel across a plus or minus sign.

**Fractions and order of operations.** When a problem has several operations, follow the usual order: parentheses first, then multiplication and division from left to right, then addition and subtraction. In  $\frac{7}{8} + \frac{5}{12} \cdot \frac{3}{5}$ , do the multiplication first ( $\frac{5}{12} \cdot \frac{3}{5} = \frac{1}{4}$ ), and then add:  $\frac{7}{8} + \frac{2}{8} = \frac{9}{8}$ .

## Worked Examples

### EXAMPLE 1: ADD UNLIKE FRACTIONS

Find  $\frac{3}{4} + \frac{5}{6}$ .

#### SOLUTION

The least common multiple of 4 and 6 is 12.

$$\frac{3}{4} = \frac{9}{12} \text{ and } \frac{5}{6} = \frac{10}{12}.$$

$$\frac{9}{12} + \frac{10}{12} = \frac{19}{12}, \text{ which is } 1\frac{7}{12} \text{ as a mixed number.}$$

### EXAMPLE 2: SUBTRACT MIXED NUMBERS

Find  $5\frac{1}{3} - 2\frac{3}{4}$ .

#### SOLUTION

Change to improper fractions:  $5\frac{1}{3} = \frac{16}{3}$  and  $2\frac{3}{4} = \frac{11}{4}$ .

Use denominator 12:  $\frac{64}{12} - \frac{33}{12} = \frac{31}{12}$ .

Convert back:  $31 \div 12 = 2$  remainder 7, so the answer is  $2\frac{7}{12}$ .

Estimate to check:  $5.3 - 2.75 \approx 2.6$ , and  $2\frac{7}{12} \approx 2.58$ . Good.

### EXAMPLE 3: MULTIPLY AND CANCEL

Find  $\frac{2}{3} \cdot \frac{9}{10}$ .

#### SOLUTION

Cancel before multiplying: 3 and 9 share a factor of 3, and 2 and 10 share a factor of 2.

$$\frac{2}{3} \cdot \frac{9}{10} = \frac{1}{1} \cdot \frac{3}{5} = \frac{3}{5}.$$

Without canceling you would get  $\frac{18}{30}$ , which also simplifies to  $\frac{3}{5}$ .

### EXAMPLE 4: DIVIDE MIXED NUMBERS

Find  $3\frac{1}{2} \div 1\frac{3}{4}$ .

#### SOLUTION

Change to improper fractions:  $\frac{7}{2} \div \frac{7}{4}$ .

Multiply by the reciprocal:  $\frac{7}{2} \cdot \frac{4}{7}$ .

Cancel the 7s and reduce 4 over 2: the result is 2.

Check:  $1\frac{3}{4} \cdot 2 = 3\frac{1}{2}$ . Yes.

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**EXAMPLE 5: A TWO-PART WORD PROBLEM**

A bakery recipe uses  $2\frac{1}{4}$  cups of flour per batch. Dana has 10 cups of flour. How many full batches can she make, and how much flour is left over?

**SOLUTION**

Number of batches:  $10 \div 2\frac{1}{4} = 10 \div \frac{9}{4} = 10 \cdot \frac{4}{9} = \frac{40}{9} = 4\frac{4}{9}$ .

Only full batches count, so she can make 4 batches.

Flour used:  $4 \cdot 2\frac{1}{4} = 4 \cdot \frac{9}{4} = 9$  cups.

Flour left:  $10 - 9 = 1$  cup. (That 1 cup is  $\frac{4}{9}$  of a batch, which matches the leftover  $\frac{4}{9}$  above.)

**EXAMPLE 6: A MULTI-STEP TRAIL PROBLEM**

A hiking trail is  $7\frac{1}{2}$  kilometers long. Sara walks  $\frac{2}{5}$  of the trail before lunch and  $1\frac{1}{4}$  kilometers after lunch. How far does she still have to walk?

**SOLUTION**

Distance before lunch:  $\frac{2}{5} \cdot 7\frac{1}{2} = \frac{2}{5} \cdot \frac{15}{2} = 3$  kilometers.

Total walked:  $3 + 1\frac{1}{4} = 4\frac{1}{4}$  kilometers.

Remaining:  $7\frac{1}{2} - 4\frac{1}{4} = \frac{30}{4} - \frac{17}{4} = \frac{13}{4} = 3\frac{1}{4}$  kilometers.

Check by estimate:  $7.5 - 4.25 = 3.25$ . Yes.

## Coach's Playbook

- 1 Name the operation.** Circle the sign. Words like "total" suggest adding, "how much more" suggests subtracting, "of" suggests multiplying, and "how many pieces" or "split into" suggests dividing.
  - 2 Convert mixed numbers.** For multiplication and division, write every mixed number as an improper fraction first.
  - 3 Set up the rule.** Add or subtract: common denominator. Multiply: cancel, then straight across. Divide: keep the first, change division to multiplication, flip the second.
  - 4 Simplify at the end.** Reduce, and turn improper fractions into mixed numbers if the problem started with mixed numbers.
  - 5 Estimate to check.** Round each fraction to a nearby benchmark ( $0$ ,  $\frac{1}{2}$ ,  $1$ ,  $2$ ). If your answer is far from the estimate, look for a slip.
- ◆ Multiplying by a fraction less than 1 makes a number smaller. Dividing by a fraction less than 1 makes a number bigger. If your answer disagrees, you probably flipped the wrong fraction.
  - ◆ When a word problem asks "how many full" containers, round down. When it asks "how many are needed to hold everything," round up.

### Common traps

(1) Adding denominators:  $\frac{1}{2} + \frac{1}{3}$  is not  $\frac{2}{5}$ . (2) Flipping the first fraction, or both, when dividing. Only the second fraction flips. (3) Multiplying the whole numbers and the fractions of mixed numbers separately, so that  $2\frac{1}{2} \cdot 1\frac{1}{3}$  becomes  $2\frac{1}{6}$ . (4) Finding a common denominator when multiplying, which is not necessary and can create huge numbers.

## Mistake Clinic

### Spot the error

**Problem:** Find  $\frac{1}{2} + \frac{1}{3}$ . **Student's work:**  $\frac{1+1}{2+3} = \frac{2}{5}$ . **What went wrong:** The student added the numerators and the denominators. The denominators name the size of the pieces, and halves and thirds are different sizes. The answer  $\frac{2}{5}$  is also less than  $\frac{1}{2}$ , which cannot be right because we added something to  $\frac{1}{2}$ . **Correct solution:** Use the common denominator 6:  $\frac{3}{6} + \frac{2}{6} = \frac{5}{6}$ .

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**Spot the error**

**Problem:** Find  $\frac{3}{4} \div \frac{1}{2}$ . **Student's work:**  $\frac{3}{4} \cdot \frac{1}{2} = \frac{3}{8}$ . **What went wrong:** The student did not take the reciprocal of the second fraction, so the division became a multiplication. The answer  $\frac{3}{8}$  is less than  $\frac{3}{4}$ , but dividing by one half should make the number bigger (there are 1.5 halves in  $\frac{3}{4}$ ). **Correct solution:** Keep the first fraction, change division to multiplication, and flip the second fraction:  $\frac{3}{4} \cdot \frac{2}{1} = \frac{6}{4} = \frac{3}{2} = 1\frac{1}{2}$ .

**Spot the error**

**Problem:** Find  $2\frac{1}{2} \cdot 3$ . **Student's work:**  $2 \cdot 3 = 6$ , and the  $\frac{1}{2}$  stays, so the answer is  $6\frac{1}{2}$ . **What went wrong:** The student multiplied only the whole-number part. The fraction part also needs to be multiplied by 3. **Correct solution:** Change to an improper fraction:  $\frac{5}{2} \cdot 3 = \frac{15}{2} = 7\frac{1}{2}$ . Or distribute:  $2 \cdot 3 + \frac{1}{2} \cdot 3 = 6 + 1\frac{1}{2} = 7\frac{1}{2}$ .

**Real-World Connection**

A carpenter has a board that is  $\frac{3}{4}$  of a meter long and needs pieces that are  $\frac{3}{16}$  of a meter. The division  $\frac{3}{4} \div \frac{3}{16} = \frac{3}{4} \cdot \frac{16}{3} = 4$  tells her she can cut exactly 4 pieces.

**Challenge Corner**

A number is multiplied by  $\frac{3}{4}$ , and then  $\frac{5}{6}$  is added to the result. The final answer is  $2\frac{1}{3}$ . What is the number? **Solution:** Work backwards. First undo the addition:  $2\frac{1}{3} - \frac{5}{6} = \frac{14}{6} - \frac{5}{6} = \frac{9}{6} = \frac{3}{2}$ . Now undo the multiplication by dividing by  $\frac{3}{4}$ :  $\frac{3}{2} \div \frac{3}{4} = \frac{3}{2} \cdot \frac{4}{3} = 2$ . The number is 2. Check:  $2 \cdot \frac{3}{4} = \frac{3}{2}$  and  $\frac{3}{2} + \frac{5}{6} = \frac{14}{6} = 2\frac{1}{3}$ .

**Practice****PRACTICE Adding, Subtracting, Multiplying, and Dividing Fractions**

Show your work on paper. Use a calculator only when a problem says so, or if it is allowed at your level.

- What is  $\frac{2}{5} + \frac{3}{10}$ ?  
(A)  $\frac{5}{15}$  (B)  $\frac{1}{2}$  (C)  $\frac{7}{10}$  (D)  $\frac{6}{50}$
- What is  $\frac{7}{8} - \frac{1}{3}$ ?  
(A)  $\frac{13}{24}$  (B)  $\frac{6}{5}$  (C)  $\frac{1}{4}$  (D)  $\frac{29}{24}$
- What is  $\frac{4}{9} \cdot \frac{3}{8}$ ?  
(A)  $\frac{12}{17}$  (B)  $\frac{32}{27}$  (C)  $\frac{1}{3}$  (D)  $\frac{1}{6}$
- What is  $\frac{3}{5} \div \frac{9}{10}$ ?  
(A)  $\frac{27}{50}$  (B)  $\frac{2}{3}$  (C)  $\frac{3}{2}$  (D)  $\frac{1}{6}$
- What is  $2\frac{1}{2} \cdot 1\frac{1}{3}$ ?  
(A)  $2\frac{1}{6}$  (B)  $3\frac{5}{6}$  (C)  $3\frac{1}{3}$  (D)  $4\frac{1}{2}$
- What is  $6\frac{1}{4} - 2\frac{5}{6}$ ?  
(A)  $3\frac{5}{12}$  (B)  $3\frac{7}{12}$  (C)  $4\frac{7}{12}$  (D)  $3\frac{1}{12}$
- A pitcher holds  $3\frac{3}{4}$  cups of juice. Each glass holds  $\frac{3}{8}$  cup. How many glasses can be filled?  
(A)  $\frac{1}{10}$  (B) 10 (C)  $1\frac{13}{32}$  (D)  $4\frac{1}{8}$
- What is  $\frac{5}{6} - \frac{1}{4} + \frac{1}{3}$ ?  
(A)  $\frac{7}{12}$  (B)  $\frac{1}{4}$  (C)  $1\frac{1}{12}$  (D)  $\frac{11}{12}$
- Three fourths of a number is 18. What is the number?  
(A)  $13\frac{1}{2}$  (B)  $22\frac{1}{2}$  (C) 24 (D)  $18\frac{3}{4}$
- A bag holds  $5\frac{1}{3}$  pounds of rice. Each scoop uses  $\frac{2}{3}$  of a pound. How many scoops can be filled?
- Tom spent  $\frac{1}{3}$  of his money on a book. Then he spent  $\frac{1}{4}$  of what he had left on lunch. What fraction of his original money does he have now?

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12. Find  $\frac{7}{8} + \frac{5}{12} - \frac{1}{3}$ .
13. A garden is  $4\frac{1}{2}$  meters long and  $2\frac{2}{3}$  meters wide. One bag of mulch covers  $\frac{3}{4}$  of a square meter. How many bags are needed to cover the whole garden?
14. Evaluate  $\frac{2}{3} \div (\frac{1}{2} + \frac{1}{3})$ .
15. A water tank is  $\frac{5}{8}$  full. After 15 liters are used, it is  $\frac{3}{8}$  full. How many liters does the tank hold when full?

01.3

Decimals and Place Value

Understand place value, compare and order decimals, calculate with them, convert between fractions and decimals including repeating ones, and use rounding and estimation to catch mistakes.

Why This Matters

Decimals are fractions written in a different outfit, and you meet them every day: prices, measurements, scores, gas gauges, and sports statistics. Calculators and phones show decimals, so being able to read, estimate, and check them is a real-life survival skill. In science and finance classes almost every number you use will be a decimal.

Students struggle for three main reasons. First, they think a decimal with more digits is larger (0.35 versus 0.4). Second, they lose track of the decimal point when multiplying or dividing. Third, they treat a calculator answer as automatically right even when a typing slip gives a nonsense result. This section gives you place-value understanding, clear procedures, and estimation habits that catch mistakes before they cost you points.

Core Ideas

Our number system is built on powers of ten. Each place is ten times the one to its right. To the right of the decimal point, the places get ten times smaller: tenths, hundredths, thousandths. So in 3.746, the 7 means 7 tenths, the 4 means 4 hundredths, and the 6 means 6 thousandths.

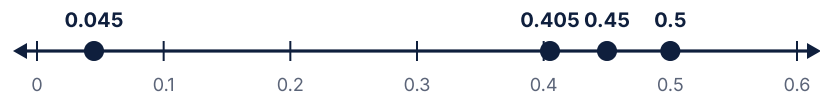
| Place          | Ones | Tenths         | Hundredths      | Thousandths      |
|----------------|------|----------------|-----------------|------------------|
| Digit in 3.746 | 3    | 7              | 4               | 6                |
| Value          | 3    | $\frac{7}{10}$ | $\frac{4}{100}$ | $\frac{6}{1000}$ |
| As a decimal   | 3    | 0.7            | 0.04            | 0.006            |

Comparing Decimals

Line up the decimal points and compare digits from the left, place by place. You may add zeros at the end of a decimal without changing its value, so  $0.7 = 0.70 = 0.700$ .

The first place where the digits differ decides which number is larger. The number of digits does NOT matter.

For example, compare 0.45, 0.405, and 0.5. Write them as 0.450, 0.405, and 0.500. In the tenths place we have 4, 4, and 5, so 0.5 is the largest. For the other two, the hundredths digits are 5 and 0, so 0.450 is larger than 0.405.



On a number line, 0.5 sits farthest right even though 0.045 has more digits. Longer decimals are not bigger.

Operations with Decimals

Add or subtract: line up the decimal points, fill empty places with zeros, then work like whole numbers. The decimal point in the answer lines up too.

Multiply: ignore the decimal points and multiply as whole numbers. Then count the total number of decimal places in both factors, and put that many decimal places in the product.

Divide: if the divisor (the number you divide by) has decimal places, move the decimal point right in both numbers by the same number of places until the divisor is a whole number. Then divide, keeping the decimal point in the quotient directly above its place in the dividend.

**Converting.** To change a fraction to a decimal, divide the numerator by the denominator:  $\frac{7}{16} = 7 \div 16 = 0.4375$ . To change a decimal to a fraction, read it using place value and simplify:  $0.36 = \frac{36}{100} = \frac{9}{25}$ . A decimal that ends is called a **terminating decimal**. Many fractions do not end. The fraction  $\frac{1}{3}$  becomes  $0.3333\dots$ , which we write as  $0.\overline{3}$ . The bar marks the digits that repeat forever. For example,  $\frac{5}{6} = 0.8\overline{3}$  and  $\frac{7}{11} = 0.6\overline{3}$ .

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| Fraction      | Decimal           | Type        |
|---------------|-------------------|-------------|
| $\frac{1}{2}$ | 0.5               | terminating |
| $\frac{1}{4}$ | 0.25              | terminating |
| $\frac{1}{8}$ | 0.125             | terminating |
| $\frac{1}{3}$ | $0.\overline{3}$  | repeating   |
| $\frac{2}{3}$ | $0.\overline{6}$  | repeating   |
| $\frac{1}{6}$ | $0.1\overline{6}$ | repeating   |

## Rounding

To round to a place, look at the digit just to the right. If it is 5 or more, round the place digit up. If it is 4 or less, leave the place digit alone. Then drop everything to the right.

To **estimate**, round each number to one nonzero digit first, then compute.



3.746 is closer to 3.75 than to 3.74, so it rounds to 3.75 to the nearest hundredth.

## Worked Examples

### EXAMPLE 1: ORDERING DECIMALS

Put 0.45, 0.405, 0.5, and 0.045 in order from least to greatest.

#### SOLUTION

Give each the same number of places: 0.450, 0.405, 0.500, 0.045.

Compare the tenths digits: 0.045 has 0, 0.405 has 4, 0.450 has 4, and 0.500 has 5. So 0.045 is smallest and 0.5 is largest.

Break the tie between 0.405 and 0.450 in the hundredths place: the digits are 0 and 5, so 0.405 is smaller.

Order: 0.045, 0.405, 0.45, 0.5.

### EXAMPLE 2: ADDING AND SUBTRACTING

Find  $12.7 + 3.456 - 5.08$ .

#### SOLUTION

Add first. Line up the points: 12.700 plus 3.456 gives 16.156.

Subtract: 16.156 minus 5.080 gives 11.076.

Estimate:  $13 + 3 - 5 = 11$ . The exact answer 11.076 is close, so it passes the check.

### EXAMPLE 3: MULTIPLYING WITH AN ESTIMATE

Find  $3.2 \times 0.045$ .

#### SOLUTION

Estimate first:  $3 \times 0.05 = 0.15$ .

Ignore the points:  $32 \times 45 = 1440$ .

Count decimal places: 3.2 has 1 and 0.045 has 3, so the product has 4 decimal places.

Place the point: 0.1440, which is 0.144.

The answer is close to the estimate of 0.15.

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**EXAMPLE 4: DIVIDING BY A DECIMAL**

Find  $7.56 \div 0.18$ .

**SOLUTION**

The divisor 0.18 has 2 decimal places, so move both points right 2 places:  $756 \div 18$ .

$18 \times 40 = 720$ , and  $756 - 720 = 36$ , and  $36 \div 18 = 2$ .

So the quotient is 42.

Check:  $0.18 \times 42 = 7.56$ . Yes.

**EXAMPLE 5: CONVERTING AND ROUNDING**

(a) Write  $\frac{7}{16}$  as a decimal. (b) Write  $\frac{5}{12}$  as a decimal and round to the nearest hundredth. (c) Write 0.36 as a fraction in simplest form.

**SOLUTION**

(a) Divide  $7 \div 16$ . Long division gives 0.4375, and it ends.

(b)  $5 \div 12 = 0.41666\ldots = 0.41\overline{6}$ . The digit after the hundredths place is 6, which is 5 or more, so round up: 0.42.

(c)  $0.36 = \frac{36}{100}$ . Divide top and bottom by 4:  $\frac{9}{25}$ .

**EXAMPLE 6: DIVIDING WITH A REMAINDER**

A ribbon is 7.5 meters long. Pieces that are 0.6 meter long are cut from it. How many full pieces can be cut, and how much ribbon is left over?

**SOLUTION**

Divide:  $7.5 \div 0.6$ . Move both decimal points one place right to get  $75 \div 6 = 12.5$ .

Only whole pieces count, so 12 full pieces can be cut.

Ribbon used:  $12 \times 0.6 = 7.2$  meters.

Left over:  $7.5 - 7.2 = 0.3$  meter.

Check: the leftover 0.3 meter is half of a piece (0.6), which matches the ".5" in 12.5.

**Coach's Playbook**

- 1 Estimate first.** Round to friendly numbers and compute in your head. This tells you the size of the answer and where the decimal point must land.
  - 2 Line up, then work.** For adding and subtracting, write the numbers in a column with decimal points stacked and add zeros so every row is the same length.
  - 3 Count the places.** When you multiply, add up the decimal places in the factors. When you divide, make the divisor a whole number.
  - 4 Compare with the estimate.** If your exact answer is ten times too big or too small, the decimal point is misplaced.
  - 5 Round only at the end.** Keep all the digits while working, and round once at the very end.
- ◆ Memorize the anchors:  $0.5 = \frac{1}{2}$ ,  $0.25 = \frac{1}{4}$ ,  $0.75 = \frac{3}{4}$ ,  $0.2 = \frac{1}{5}$ ,  $0.125 = \frac{1}{8}$ ,  $0.\overline{3} = \frac{1}{3}$ .
  - ◆ Multiplying by 10 moves the decimal point one place to the right. Dividing by 10 moves it one place to the left.
  - ◆ A fraction in simplest form terminates only if its denominator has no prime factors other than 2 and 5.

**Common traps**

(1) Thinking 0.35 is greater than 0.4 because 35 is greater than 4. Compare place by place. (2) Lining up the digits on the right instead of lining up the decimal points when adding. (3) Forgetting to count decimal places in a product:  $0.6 \times 0.07$  is 0.042, not 0.42. (4) Rounding too early, or rounding up when the next digit is a 4 (3.743 rounded to the nearest hundredth is 3.74, not 3.75).

**Mistake Clinic**

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**Spot the error**

**Problem:** Which is greater, 0.35 or 0.4? **Student's work:** 35 is bigger than 4, so 0.35 is greater. **What went wrong:** The student compared the digits as whole numbers. Decimals must be compared place by place after the points are lined up. **Correct solution:** Write 0.4 as 0.40. Tenths: 4 versus 3, so 0.40 is greater. The answer is 0.4.

**Spot the error**

**Problem:** Find  $4.5 + 2.37$ . **Student's work:** Write 4.5 above 2.37, lined up on the right, and add the digits to get 2.82. **What went wrong:** The student lined up the digits on the right instead of lining up the decimal points. That added 4.5 tenths to 2.37 hundredths in places that do not match, and the result (2.82) is smaller than 4.5, which is impossible. **Correct solution:** Write 4.50 above 2.37 so the points line up: 4.50 plus 2.37 equals 6.87.

**Spot the error**

**Problem:** Find  $0.6 \times 0.07$ . **Student's work:**  $6 \times 7 = 42$ , so the answer is 0.42. **What went wrong:** The student did not count all the decimal places. The factors have 1 and 2 decimal places, so the product needs 3. **Correct solution:**  $6 \times 7 = 42$  with 3 decimal places is 0.042. Estimate:  $0.6 \times 0.07$  is about  $0.5 \times 0.1 = 0.05$ , so 0.042 is reasonable and 0.42 is not.

**Real-World Connection**

Gas stations price fuel in tenths of a cent, and a sports timer measures a race to the hundredth of a second. When two sprinters finish in 11.52 and 11.5 seconds, the 11.50 runner is faster by two hundredths. Place value decides the winner.

**Challenge Corner**

Write  $0.\overline{45}$  as a fraction in simplest form, and decide which is greater:  $0.\overline{45}$  or  $0.4\overline{5}$ . **Solution:** Let  $x = 0.454545\ldots$ . Because two digits repeat, multiply by 100:  $100x = 45.454545\ldots$ . Subtract:  $100x - x = 45$ , so  $99x = 45$  and  $x = \frac{45}{99} = \frac{5}{11}$ . Now line up the digits:  $0.\overline{45} = 0.454545\ldots$  and  $0.4\overline{5} = 0.455555\ldots$ . They agree through the hundredths. In the thousandths place the first has 4 and the second has 5, so  $0.4\overline{5}$  is greater.

**Practice****PRACTICE** Decimals and Place Value

Show your work on paper. Use a calculator only when a problem says so, or if it is allowed at your level.

- Which decimal is the greatest?  
(A) 0.7 (B) 0.709 (C) 0.68 (D) 0.0715
- What is  $8.4 - 2.057$ ?  
(A) 6.457 (B) 5.343 (C) 6.357 (D) 6.343
- What is  $0.6 \times 0.07$ ?  
(A) 0.042 (B) 0.42 (C) 0.0042 (D) 0.67
- What is  $5.04 \div 0.8$ ?  
(A) 0.63 (B) 6.3 (C) 63 (D) 0.063
- Which decimal is equal to  $\frac{7}{8}$ ?  
(A) 0.78 (B) 0.7 (C) 0.875 (D) 0.825
- What is 4.0763 rounded to the nearest hundredth?  
(A) 4.07 (B) 4.1 (C) 4.076 (D) 4.08

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7. Which fraction is equal to a repeating decimal?  
(A)  $\frac{2}{9}$  (B)  $\frac{1}{4}$  (C)  $\frac{3}{8}$  (D)  $\frac{7}{20}$
8. A 2.5 kilogram bag of flour costs 3.60 dollars. What is the price per kilogram?  
(A) 0.69 dollars (B) 9.00 dollars (C) 1.44 dollars  
(D) 6.10 dollars
9. Which is the best estimate of  $19.8 \times 4.1$ ?  
(A) 8 (B) 80 (C) 800 (D) 24
10. Write 0.375 as a fraction in simplest form.
11. Write  $\frac{7}{11}$  as a repeating decimal. Use a bar over the repeating digits.
12. Four laps took 1.25, 1.18, 1.2, and 1.32 minutes. What was the average lap time, rounded to the nearest hundredth of a minute?
13. Ana buys 6 notebooks at 2.35 dollars each and 3 packs of pens at 4.75 dollars each. She pays with a 50-dollar bill. How much change should she get, in dollars?
14. Write 0.0625 as a fraction in simplest form.
15. A bread recipe needs 0.75 kilogram of flour per loaf. Jo has 6.3 kilograms of flour. How many full loaves can she make, and how much flour is left over?

01.4

Percents in Real Life

Use the percent equation to find a part, a whole, or a percent, then apply it to percent change, discounts, tax, tips, and simple interest with confidence.

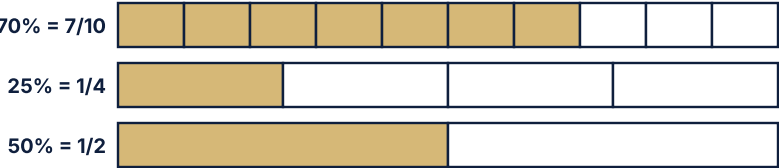
Why This Matters

Percents are the language of money and data. Sale signs, sales tax, tips, interest on a savings account, test scores, battery levels, and election polls are all percents. If you can handle them, you can spot a good deal, check a bill, and understand news reports. Later courses use percents in probability, statistics, chemistry mixtures, and finance.

Students typically struggle with three things: knowing which number is the whole, deciding whether to multiply or divide, and calculating percent change (a 20 percent increase followed by a 20 percent decrease does not bring you back to the start). This section teaches one simple model, the percent equation, and shows how to use it for every common situation.

Core Ideas

The word **percent** means "per hundred." So 7 percent, written 7%, means 7 out of every 100, or  $\frac{7}{100} = 0.07$ . To change a percent to a decimal, move the decimal point two places left. To change a decimal to a percent, move it two places right.



A percent is just a fraction with denominator 100. Each bar shows a different percent of the same whole.

| Percent | Decimal | Fraction       |
|---------|---------|----------------|
| 10%     | 0.1     | $\frac{1}{10}$ |
| 20%     | 0.2     | $\frac{1}{5}$  |
| 25%     | 0.25    | $\frac{1}{4}$  |
| 50%     | 0.5     | $\frac{1}{2}$  |
| 75%     | 0.75    | $\frac{3}{4}$  |
| 5%      | 0.05    | $\frac{1}{20}$ |

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## The Percent Equation

$$\text{part} = \text{percent} \times \text{whole}$$

Write the percent as a decimal. Every percent problem gives you two of the three pieces and asks for the third.

Find the **part**: multiply. Find the **whole**: divide the part by the decimal percent. Find the **percent**: divide the part by the whole, then convert to a percent.

The whole is the number that the percent is "of." In "18 is 30% of what number?", the whole is the unknown, so you divide:  $18 \div 0.30 = 60$ . In "What is 35% of 240?", the whole is 240, so you multiply:  $0.35 \times 240 = 84$ .

## Percent Change

$$\text{percent change} = \frac{\text{new} - \text{old}}{\text{old}} \times 100\%$$

A positive result is an increase and a negative result is a decrease. The denominator is always the **original** (old) amount.



The price went from 80 to 92 dollars. The change is 12 dollars, and 12 out of the original 80 is 15%.

**Multipliers** make multi-step problems fast. Adding 8% tax means paying  $100\% + 8\% = 108\%$  of the price, so multiply by 1.08. A 25% discount means paying 75%, so multiply by 0.75. A 20% increase means multiply by 1.20. One multiplication replaces two steps.

**Simple interest** is money earned on the original amount only. If you invest a principal  $P$  at an annual rate  $r$  (as a decimal) for  $t$  years, the interest is  $I = Prt$ , and the total is  $P + I$ .

**Why percent change uses the old amount.** The question "how much did it change?" is always asked relative to where you started. If a 50-dollar item rises to 60 dollars, the change is 10 dollars and the starting price was 50, so the increase is  $\frac{10}{50} = 20\%$ . If it falls back from 60 to 50, the change is still 10 dollars but now the starting price is 60, so the decrease is only  $\frac{10}{60} \approx 16.7\%$ . That is the reason a 20% increase and a 20% decrease do not cancel.

**Percents bigger than 100%.** A percent can be more than 100 when the part is larger than the whole. If a plant was 20 centimeters tall and is now 50 centimeters tall, it is 250% of its old height ( $50 \div 20 = 2.5$ ), which is an increase of 150%. Likewise, a percent can be smaller than 1%, such as 0.5%, which is  $\frac{5}{1000}$ .

**Mental math with benchmarks.** You can build almost any percent from 10% and 1%. For 35% of 240: 10% is 24, so 30% is 72, and 5% is half of 10%, which is 12. Add them: 84. For 15% of any amount, find 10% and add half of it. For 25%, take a quarter. For 75%, take a quarter and subtract it from the whole.

## Worked Examples

### EXAMPLE 1: PERCENT OF A NUMBER

What is 35% of 240?

#### SOLUTION

Write 35% as 0.35.

Multiply:  $0.35 \times 240 = 84$ .

Shortcut check: 10% of 240 is 24, so 30% is 72, and 5% is 12. Then  $72 + 12 = 84$ .

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**EXAMPLE 2: FINDING THE WHOLE**

A school collected 18 cans, which is 30% of its goal. What is the goal?

**SOLUTION**

The 18 cans are the part and the goal is the whole.

Use  $\text{part} = \text{percent} \times \text{whole}$ :  $18 = 0.30 \times \text{whole}$ .

Divide:  $\text{whole} = 18 \div 0.30 = 60$ .

Check: 30% of 60 is 18. Yes.

**EXAMPLE 3: PERCENT CHANGE**

(a) A game console goes from 80 dollars to 92 dollars. Find the percent increase. (b) A phone battery drops from 50% to 38%. Find the percent decrease in the battery level.

**SOLUTION**

(a) Change:  $92 - 80 = 12$ . Divide by the old value:  $12 \div 80 = 0.15$ . That is a 15% increase.

(b) Change:  $50 - 38 = 12$ . Divide by the old value:  $12 \div 50 = 0.24$ . That is a 24% decrease.

Notice that both changes are 12, but the percent change is different because the starting values are different.

**EXAMPLE 4: DISCOUNT, THEN TAX**

A jacket costs 64 dollars. It is on sale for 25% off, and then 8% sales tax is added to the sale price. What is the final cost?

**SOLUTION**

Sale price: multiply by 0.75.  $64 \times 0.75 = 48$  dollars.

Tax: multiply by 1.08.  $48 \times 1.08 = 51.84$  dollars.

The final cost is 51.84 dollars.

Note that the tax is on the sale price, not the original price.

**EXAMPLE 5: SIMPLE INTEREST**

Marcus puts 1,200 dollars into an account that pays 4% simple interest per year. How much interest does he earn in 3 years, and what is the account worth then?

**SOLUTION**

Use  $I = Prt$  with  $P = 1200$ ,  $r = 0.04$ ,  $t = 3$ .

$I = 1200 \times 0.04 \times 3 = 144$  dollars.

Total:  $1200 + 144 = 1344$  dollars.

With simple interest, the same 48 dollars is earned each year (4% of 1,200).

**EXAMPLE 6: TWO CHANGES IN A ROW**

A store marks a 60-dollar pair of sneakers up by 25%. Later, it takes 20% off the new price. What is the final price, and what is the overall percent change from the original 60 dollars?

**SOLUTION**

Mark-up multiplier: 1.25. New price:  $60 \times 1.25 = 75$  dollars.

Discount multiplier: 0.80. Final price:  $75 \times 0.80 = 60$  dollars.

Overall change:  $60 - 60 = 0$ , so the overall percent change is 0%.

Chain the multipliers to see why:  $1.25 \times 0.80 = 1.00$ . A 25% increase is exactly undone by a 20% decrease, because the decrease is taken from the larger amount.

## Coach's Playbook

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- 1 **Find the whole.** Look for the word "of" or the starting amount. That is the whole, and it goes in the denominator for percent change.
  - 2 **Convert to a decimal.** Change the percent to a decimal before you calculate.
  - 3 **Choose the operation.** Looking for the part: multiply. Looking for the whole: divide. Looking for the percent: divide part by whole.
  - 4 **Use multipliers for multi-step problems.** 1.15 adds 15%, 0.85 takes off 15%, and chains of multipliers stack.
  - 5 **Sense-check.** A discount must make the price smaller, and a tip must make the total larger.
- ◆ **10% trick:** move the decimal one place left. Then 5% is half of that and 20% is double.
  - ◆ **Tip trick:** to find a 15% tip, find 10% and add half of it. For a 48 dollar bill: 4.80 plus 2.40 gives 7.20 dollars.
  - ◆ **Order matters:** a 20% increase followed by a 20% decrease leaves you at 96% of the start, because  $1.2 \times 0.8 = 0.96$ .

### Common traps

(1) Using the new amount instead of the old amount in the denominator of percent change. (2) Taking a percent of the wrong number, such as finding tax on the original price instead of the sale price. (3) Adding two successive percent changes (a 20% discount and then 10% off is not 30% off). (4) Forgetting to turn the percent into a decimal, which makes answers 100 times too big.

## Mistake Clinic

### Spot the error

**Problem:** A game price goes from 40 dollars to 50 dollars. Find the percent increase. **Student's work:** The change is 10 dollars.  $10 \div 50 = 0.20$ , so the increase is 20%. **What went wrong:** The student divided by the new price. Percent change always compares the change with the original amount. **Correct solution:**  $10 \div 40 = 0.25$ , so the price increased by 25%.

### Spot the error

**Problem:** A coat costs 80 dollars. It is 25% off, and then an extra 10% off. What is the final price? **Student's work:** 25% plus 10% is 35% off.  $80 \times 0.65 = 52$  dollars. **What went wrong:** The student added the percents. The second discount is taken off the already reduced price, which is smaller than 80, so it takes off less than 10% of 80. **Correct solution:** Multiply the multipliers:  $80 \times 0.75 = 60$ , then  $60 \times 0.90 = 54$  dollars. The two discounts are worth 32.5% off, not 35%.

### Spot the error

**Problem:** 12 is what percent of 48? **Student's work:**  $48 \div 12 = 4$ , so the answer is 4%. **What went wrong:** The student divided the whole by the part, and also forgot that 4 as a decimal is 400%, not 4%. The part is smaller than the whole, so the percent must be less than 100%. **Correct solution:** Divide part by whole:  $12 \div 48 = 0.25$ . As a percent, that is 25%.

### Real-World Connection

Bank loans and savings accounts quote an annual rate. A 5% rate on 900 dollars for 6 years earns 270 dollars of simple interest. Knowing how that is computed helps you compare offers.

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**Challenge Corner**

After a 20% discount and then 5% sales tax, a shirt cost 33.60 dollars in all. What was the original price of the shirt?

**Solution:** Use multipliers. A 20% discount is  $\times 0.80$  and 5% tax is  $\times 1.05$ , so the final amount is  $\text{original} \times 0.80 \times 1.05 = \text{original} \times 0.84$ . Then  $\text{original} \times 0.84 = 33.60$ , so the original price is  $33.60 \div 0.84 = 40$  dollars. Check:  $40 \times 0.80 = 32$  and  $32 \times 1.05 = 33.60$ .

**Practice****PRACTICE Percents in Real Life**

Show your work on paper. Use a calculator only when a problem says so, or if it is allowed at your level.

- What is 15% of 80?  
(A) 1.2 (B) 8 (C) 12 (D) 120
- 9 is what percent of 36?  
(A) 25% (B) 4% (C) 400% (D) 9%
- A 40-dollar shirt is on sale for 30% off. What is the sale price?  
(A) 12 dollars (B) 52 dollars (C) 30 dollars  
(D) 28 dollars
- 45 is 60% of what number?  
(A) 27 (B) 75 (C) 108 (D) 270
- A town grows from 800 people to 1,000 people. What is the percent increase?  
(A) 20% (B) 200% (C) 25% (D) 125%
- How much simple interest does 2,500 dollars earn at 3% per year in 4 years?  
(A) 300 dollars (B) 75 dollars (C) 3,000 dollars  
(D) 103 dollars
- What is 0.5% of 600?  
(A) 300 (B) 30 (C) 3 (D) 0.3
- The price of a pair of headphones falls from 60 dollars to 45 dollars. What is the percent decrease?  
(A) 15% (B) 33% (C) 75% (D) 25%
- A test has 40 questions. Lena answered 85% of them correctly. How many questions did she miss?  
(A) 34 (B) 6 (C) 8.5 (D) 15
- A restaurant bill is 48 dollars. You leave a 15% tip. What is the total, in dollars?
- A store raises the price of a 50-dollar item by 20%. Later it lowers the new price by 20%. What is the final price, in dollars?
- After a 30% discount, a bike costs 154 dollars. What was the original price, in dollars?
- Sam invests money at 5% simple interest per year. After 6 years he has earned 270 dollars in interest. How much did he invest, in dollars?
- What percent of 80 is 14?
- An account pays 6% simple interest each year. After 5 years the interest earned is 780 dollars. How much was invested at the start, in dollars?

**Answers and Explanations**

Complete solutions for every practice problem, numbered to match. Read the explanation even when your answer is right.

**01.1 Understanding and Comparing Fractions**

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**PRACTICE · UNDERSTANDING AND COMPARING FRACTIONS**

1. B.  $\frac{5 \cdot 2}{9 \cdot 2} = \frac{10}{18}$ . Choice A adds 2 to the top and bottom, which changes the value; C only changes the denominator; D gives  $\frac{5}{12}$ .
2. C. The GCF of 54 and 90 is 18, so  $\frac{54 \div 18}{90 \div 18} = \frac{3}{5}$ . The others are equivalent but can still be divided further.
3. A. Convert to decimals: 0.8, about 0.778, 0.75, about 0.733. The largest is  $\frac{4}{5}$ . Do not pick the fraction with the biggest denominator.
4. D. Multiply the whole number by the denominator:  $5 \cdot 8 = 40$ . Add the numerator:  $40 + 3 = 43$ . So  $\frac{43}{8}$ . Choice B just glues the digits together.
5. B.  $\frac{1}{3} \approx 0.333$  and  $\frac{1}{2} = 0.5$ .  $\frac{2}{5} = 0.4$  is between them.  $\frac{3}{10} = 0.3$  is too small and  $\frac{5}{8} = 0.625$  is too large.
6. C. Common denominator 24:  $\frac{3}{8} = \frac{9}{24}$  and  $\frac{5}{12} = \frac{10}{24}$ . Leo ate more, by  $\frac{10-9}{24} = \frac{1}{24}$ . Maya's denominator is bigger, which is the tempting wrong reason to pick her.
7. D. As decimals the values are 0.5, 0.6, 0.625, and about 0.667. Choice A lists them from greatest to least. Choices B and C each swap two fractions that are close together.
8. A. Divide:  $47 \div 9 = 5$  remainder 2, so  $\frac{47}{9} = 5\frac{2}{9}$ . Check:  $5 \cdot 9 + 2 = 47$ . Choices B and C reuse the digits of 47 without dividing.
9. C. Each fraction is missing one piece to make 1:  $\frac{1}{8}$ ,  $\frac{1}{10}$ ,  $\frac{1}{12}$ , and  $\frac{1}{5}$ . The smallest missing piece is  $\frac{1}{12}$ , so  $\frac{11}{12}$  is closest. The biggest numerator or denominator does not decide the answer.
10.  $1\frac{1}{2}$ . The GCF of 126 and 84 is 42, so  $\frac{126}{84} = \frac{3}{2}$ . Then  $3 \div 2 = 1$  remainder 1, giving  $1\frac{1}{2}$ .
11.  $n = 9$ . From 5 to 35 the numerator was multiplied by 7. Since  $63 \div 7 = 9$ ,  $n = 9$ . Check:  $5 \cdot 63 = 315 = 9 \cdot 35$ .
12.  $\frac{2}{3}$ ,  $\frac{7}{10}$ ,  $\frac{5}{7}$ ,  $\frac{3}{4}$ . As decimals these are about 0.667, 0.7, 0.714, and 0.75. (Common denominator 420 gives 280, 294, 300, 315 for the sorted list.)
13. 9.  $\frac{1}{4} = \frac{5}{20}$  and  $\frac{3}{4} = \frac{15}{20}$ . The numerators strictly between 5 and 15 are 6, 7, 8, 9, 10, 11, 12, 13, 14, which is 9 numbers.
14.  $\frac{3}{7}$ . The GCF of 360 and 840 is 120:  $360 \div 120 = 3$  and  $840 \div 120 = 7$ . (Dividing by 10, then 12, also works.)
15. 21.  $\frac{5}{20} = \frac{1}{4}$  exactly, which is not less. At  $n = 21$ ,  $\frac{5}{21} \approx 0.238 < 0.25$ . So the smallest whole number is 21.

**01.2 Adding, Subtracting, Multiplying, and Dividing Fractions****PRACTICE · ADDING, SUBTRACTING, MULTIPLYING, AND DIVIDING FRACTIONS**

1. C. Rewrite  $\frac{2}{5}$  as  $\frac{4}{10}$ . Then  $\frac{4}{10} + \frac{3}{10} = \frac{7}{10}$ . Choice A adds the tops and the bottoms, which is never correct.
2. A. Common denominator 24:  $\frac{21}{24} - \frac{8}{24} = \frac{13}{24}$ . Choice B subtracts the tops and the bottoms separately.
3. D. Multiply straight across:  $\frac{4 \cdot 3}{9 \cdot 8} = \frac{12}{72} = \frac{1}{6}$ . Choice B flips the second fraction as if dividing, and choice A adds across.
4. B. Multiply by the reciprocal:  $\frac{3}{5} \cdot \frac{10}{9} = \frac{30}{45} = \frac{2}{3}$ . Choice A multiplies without flipping; choice C flips the wrong fraction.
5. C. Change to improper fractions:  $\frac{5}{2} \cdot \frac{4}{3} = \frac{20}{6} = \frac{10}{3} = 3\frac{1}{3}$ . Choice A multiplies the whole parts and the fraction parts separately, which is wrong.
6. A. Improper fractions with denominator 12:  $\frac{75}{12} - \frac{34}{12} = \frac{41}{12} = 3\frac{5}{12}$ . Choice C subtracts the smaller fraction from the larger one in the wrong order; choice D is a slip in the borrowing.
7. B. Divide:  $\frac{15}{4} \div \frac{3}{8} = \frac{15}{4} \cdot \frac{8}{3} = 10$ . Choice C multiplies instead of dividing, and choice A divides in the wrong order.
8. D. Use twelfths:  $\frac{10}{12} - \frac{3}{12} + \frac{4}{12} = \frac{11}{12}$ . Choice B subtracts the last fraction by mistake, and choice A stops after the first subtraction.
9. C. Undo the multiplication by dividing:  $18 \div \frac{3}{4} = 18 \cdot \frac{4}{3} = 24$ . Check:  $\frac{3}{4}$  of 24 is 18. Choice A takes  $\frac{3}{4}$  of 18, which finds the wrong thing.
10. 8 scoops.  $5\frac{1}{3} = \frac{16}{3}$ , and  $\frac{16}{3} \div \frac{2}{3} = \frac{16}{3} \cdot \frac{3}{2} = 8$ .
11.  $\frac{1}{2}$ . After the book, he has  $1 - \frac{1}{3} = \frac{2}{3}$ . Lunch costs  $\frac{1}{4} \cdot \frac{2}{3} = \frac{1}{6}$  of the original amount. Left:  $\frac{2}{3} - \frac{1}{6} = \frac{4}{6} - \frac{1}{6} = \frac{3}{6} = \frac{1}{2}$ .
12.  $\frac{23}{24}$ . Use denominator 24:  $\frac{21}{24} + \frac{10}{24} - \frac{8}{24} = \frac{23}{24}$ .
13. 16 bags. Area =  $\frac{9}{2} \cdot \frac{8}{3} = 12$  square meters. Bags:  $12 \div \frac{3}{4} = 12 \cdot \frac{4}{3} = 16$ . It divides evenly, so no rounding is needed.
14.  $\frac{4}{5}$ . Parentheses first:  $\frac{1}{2} + \frac{1}{3} = \frac{5}{6}$ . Then  $\frac{2}{3} \div \frac{5}{6} = \frac{2}{3} \cdot \frac{6}{5} = \frac{12}{15} = \frac{4}{5}$ .
15. 60 liters. The 15 liters used equal  $\frac{5}{8} - \frac{3}{8} = \frac{2}{8} = \frac{1}{4}$  of the tank. So the full tank is  $15 \div \frac{1}{4} = 15 \cdot 4 = 60$  liters.

**01.3 Decimals and Place Value****PRACTICE · DECIMALS AND PLACE VALUE**

1. B. Write them with the same number of places: 0.7000, 0.7090, 0.6800, 0.0715. Compare place by place. The tenths digits are 7, 7, 6, 0, so 0.68 and 0.0715 are out. Between 0.7000 and 0.7090, the thousandths digits are 0 and 9, so 0.709 wins. Choice D has the most digits but is the smallest.
2. D. Line up the points: 8.400 minus 2.057 is 6.343. Choices A and C come from borrowing slips.
3. A.  $6 \times 7 = 42$ . The factors have 1 and 2 decimal places, so the product has 3 decimal places: 0.042. Choice B only counts one place.
4. B. Move the points right 1 place:  $50.4 \div 8 = 6.3$ . Check:  $0.8 \times 6.3 = 5.04$ . Choice A puts the decimal point in the wrong place.
5. C.  $7 \div 8 = 0.875$ . Choice A (0.78) just reuses the digits 7 and 8.
6. D. The hundredths digit is 7 and the next digit is 6, which is 5 or more, so round up to 4.08. Choice A drops the digits without rounding up.
7. A. A fraction in simplest form ends only if its denominator has no prime factors except 2 and 5. The denominators 4, 8, and 20 qualify, but 9 does not:  $\frac{2}{9} = 0.\overline{2}$ .
8. C. Price per kilogram is  $3.60 \div 2.5 = 1.44$ . Choice A divides in the wrong order ( $2.5 \div 3.6$ ), and choice B multiplies the two numbers.
9. B. Round to  $20 \times 4 = 80$ . Choice C has the decimal point in the wrong place, and choice D adds instead of multiplying. (The exact product is 81.18.)
10.  $\frac{3}{8}$ .  $0.375 = \frac{375}{1000}$ . Divide top and bottom by 125 to get  $\frac{3}{8}$ .
11.  $0.\overline{63}$ . Divide  $7 \div 11$ : 70 gives 6 remainder 4, 40 gives 3 remainder 7, and the remainder 7 repeats, so the digits 63 repeat.
12. 1.24 minutes. Total:  $1.25 + 1.18 + 1.2 + 1.32 = 4.95$ . Divide by 4:  $4.95 \div 4 = 1.2375$ . The thousandths digit is 7, so round the hundredths up: 1.24.
13. 21.65 dollars. Notebooks:  $6 \times 2.35 = 14.10$ . Pens:  $3 \times 4.75 = 14.25$ . Total: 28.35. Change:  $50 - 28.35 = 21.65$ .

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14.  $\frac{1}{16} \cdot 0.0625 = \frac{625}{10000}$ . Divide top and bottom by 625:  $\frac{1}{16}$ .

15. 8 loaves with 0.3 kilogram left over.  $6.3 \div 0.75 = 630 \div 75 = 8.4$ , so 8 full loaves. Flour used:  $8 \times 0.75 = 6$ . Left:  $6.3 - 6 = 0.3$  kilogram.

## 01.4 Percents in Real Life

### PRACTICE · PERCENTS IN REAL LIFE

1. C.  $0.15 \times 80 = 12$ . Choice A treats 15% as 0.015, and choice B divides 80 by 10 and subtracts, which is not the percent.
2. A. Percent =  $\frac{9}{36} = \frac{1}{4} = 25\%$ . Choice C divides the whole by the part ( $36 \div 9 = 4$ ) and calls it 400%.
3. D. A 30% discount means paying 70%:  $40 \times 0.7 = 28$ . Choice A is the amount of the discount, not the sale price.
4. B. Whole =  $45 \div 0.60 = 75$ . Choice A multiplies instead of dividing:  $0.6 \times 45 = 27$ .
5. C. Change:  $1000 - 800 = 200$ . Divide by the old amount:  $200 \div 800 = 0.25$ , or 25%. Choice A divides by the new amount.
6. A.  $I = Prt = 2500 \times 0.03 \times 4 = 300$ . Choice B is only one year of interest.
7. C. 0.5% is 0.005 as a decimal, and  $0.005 \times 600 = 3$ . Choice A uses 50%, and choice B uses 5%.
8. D. Change:  $60 - 45 = 15$ . Divide by the original:  $15 \div 60 = 0.25$ , so 25%. Choice A is the change in dollars written as a percent, and choice B divides by the new price.
9. B. Correct:  $0.85 \times 40 = 34$ . Missed:  $40 - 34 = 6$ . Choice A is the number she got right, which is what the problem does not ask for.
10. 55.20 dollars. Tip:  $0.15 \times 48 = 7.20$ . Total:  $48 + 7.20 = 55.20$ . (Or  $48 \times 1.15 = 55.20$ .)
11. 48 dollars. After the increase:  $50 \times 1.2 = 60$ . After the decrease:  $60 \times 0.8 = 48$ . It is not 50, because the 20% decrease is taken from a larger amount.
12. 220 dollars. A 30% discount leaves 70% of the price:  $0.70 \times \text{original} = 154$ . So original =  $154 \div 0.70 = 220$ .
13. 900 dollars.  $I = Prt$  gives  $270 = P \times 0.05 \times 6 = 0.3P$ . So  $P = 270 \div 0.3 = 900$ .
14. 17.5%. Percent =  $14 \div 80 = 0.175$ , which is 17.5%.
15. 2,600 dollars.  $I = Prt$  gives  $780 = P \times 0.06 \times 5 = 0.3P$ . So  $P = 780 \div 0.3 = 2600$ .

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