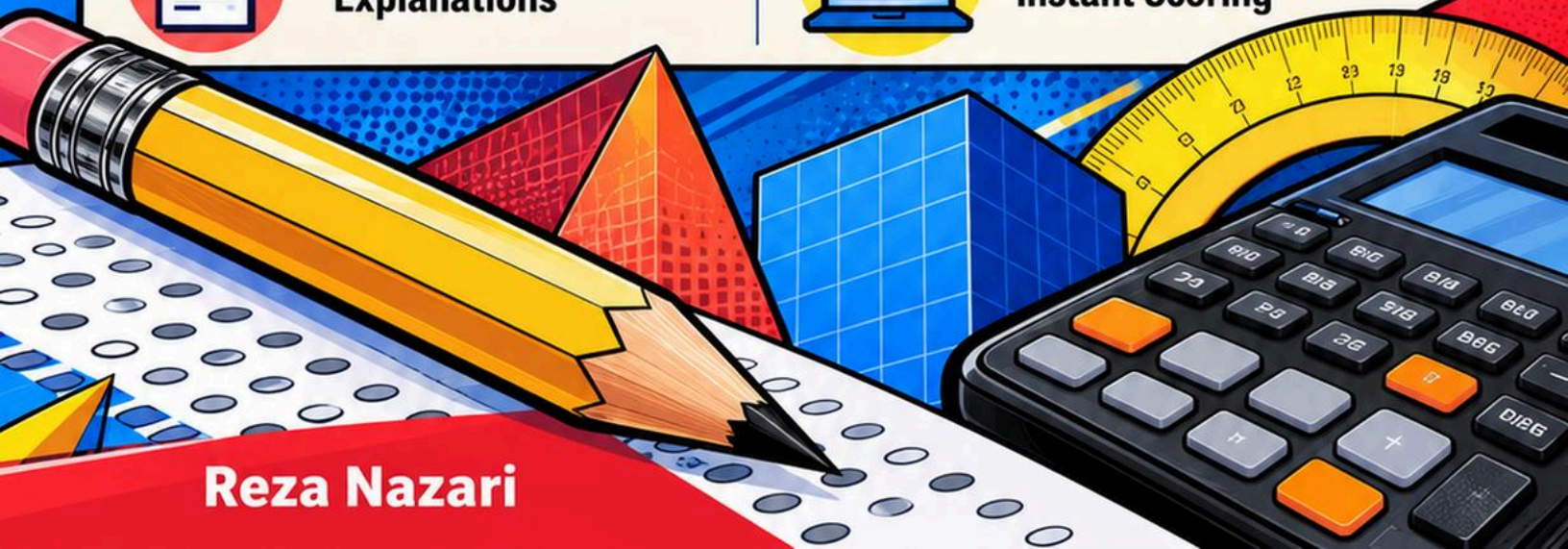
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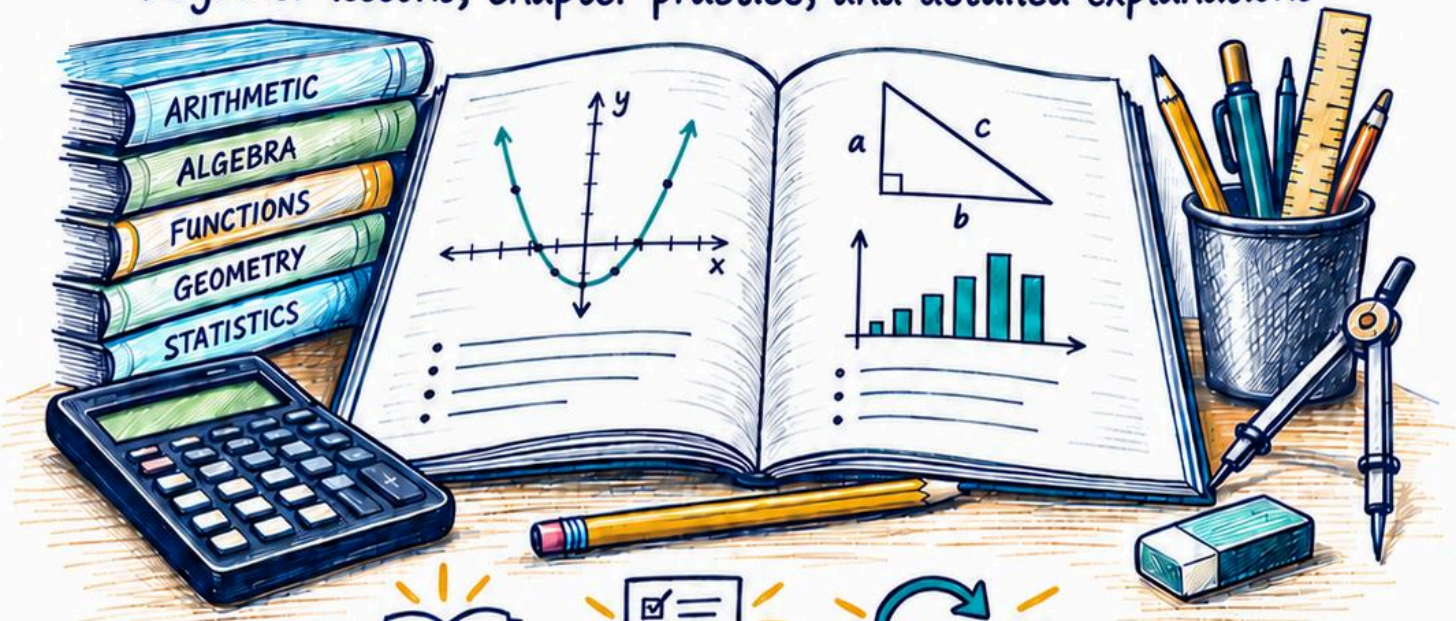
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PART I

Math Skill Lessons

ACT Math covers number relationships, algebra, functions, geometry, statistics, and probability through the beginning of Grade 12. These ideas appear in symbolic expressions, graphs, data displays, and mathematical models of everyday situations.

This part explains the concepts behind that work. The chapters begin with numerical foundations, develop equations and functions, and then connect those tools to shape, measurement, data, and chance. Read in order when you need to rebuild a foundation, or return to a particular chapter when a concept needs clarification.

1. Real Numbers and Numerical Reasoning

Number systems, ordering, and interval notation

A temperature of -3 degrees and a temperature of 2 degrees sit on opposite sides of zero. On a number line, positions increase as you move right. That gives $-3 < 2$. The symbol $<$ means "less than," and $>$ means "greater than." A longer string such as $-3 < 0 < 2$ states two comparisons at once.

Number families

The counting numbers $1, 2, 3, \ldots$ are positive integers. Whole numbers include zero. Integers also include the negatives: $\ldots, -2, -1, 0, 1, 2, \ldots$. A rational number can be written as $\frac{a}{b}$ with integers a, b and $b \neq 0$. Every integer is rational because $n = \frac{n}{1}$. In $\frac{a}{b}$, a is the numerator and b is the denominator. The fraction means a divided by b, so $\frac{3}{4}$ describes three of four equal parts of one whole. It is rational but is not an integer. An irrational number cannot be written as a ratio of integers. Examples include $\sqrt{2}$ and π. Rational and irrational numbers together form the real numbers, which are the positions on the number line.

A number may belong to several families. Zero is whole, integer, rational and real. Calling it an integer does not rule out those other descriptions. Some books include zero among the natural numbers and some begin at 1. Follow a definition supplied by a question rather than relying on that label alone.

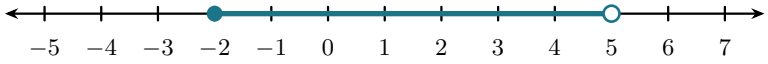
Comparing positions

Among negative numbers, the one farther left is smaller: $-8 < -3$. You can compare positive fractions by giving them a common denominator. For instance, split each sixth into two equal pieces and each fourth into three. Both amounts are now counted in twelfths: $\frac{5}{6} = \frac{5(2)}{6(2)} = \frac{10}{12}$ and $\frac{3}{4} = \frac{3(3)}{4(3)} = \frac{9}{12}$. Ten of those same-sized pieces exceed nine, so $\frac{5}{6} > \frac{3}{4}$. Their negatives reverse that order: $-\frac{5}{6} < -\frac{3}{4}$. The square of a number is that number multiplied by itself, and $\sqrt{19}$ denotes the nonnegative number whose square is 19. To compare a square root with integers, locate the number under the root between consecutive perfect squares. Since $16 < 19 < 25$, the positive square root satisfies $4 < \sqrt{19} < 5$.

For an approximation, first ask whether its precision settles the comparison. Rounding two numbers to the same decimal does not establish equality. The exact values $\frac{1}{3}$ and 0.33 differ because $\frac{1}{3} = 0.333\ldots$.

Describing a set with endpoints

An inequality describes which numbers are allowed. Here x is a placeholder for any number under consideration. The symbol $\leq$ means "less than or equal to," and $\geq$ means "greater than or equal to." For example, $x \geq 3$ allows 3 itself as well as every larger number. The statement $-2 \leq x < 5$ allows -2, excludes 5, and includes everything between them. Its interval notation is $[-2, 5)$. A bracket includes an endpoint. A parenthesis excludes it. Thus $(1, 4)$ excludes both endpoints, while $[1, 4]$ includes both.



The filled endpoint represents -2 and the open endpoint represents 5. A single interval includes all real numbers between its endpoints, including fractions. If a question asks only for integers in that interval, list those integers separately.

An unbounded set such as $x \geq 3$ has interval notation $[3, \infty)$. Infinity describes an unlimited direction, so it always takes a parenthesis. For $x < -1$ or $x \geq 2$, write $(-\infty, -1) \cup [2, \infty)$. The union symbol $\cup$ joins the two allowed sets. Check each finite endpoint against the original inequality before deciding which mark to use.

ACT-Style Question

How many integers x satisfy $-\sqrt{10} < x \leq 2$?

A. 4 **B.** 5

C. 6 **D.** 7

Since $3 < \sqrt{10} < 4$, the lower bound $-\sqrt{10}$ lies between -4 and -3. The permitted integers are $-3, -2, -1, 0, 1, 2$, giving 6 integers, choice C. The strict lower inequality still allows -3 because -3 is greater than $-\sqrt{10}$.

ACT-Style Question

A number t is greater than -4 and at most 1. Which interval represents all possible values of t?

A. $[-4, 1]$ **B.** $(-4, 1)$

C. $[-4, 1)$ **D.** $(-4, 1]$

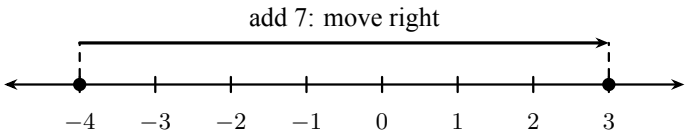
"Greater than -4" excludes -4, so the left endpoint uses a parenthesis. "At most 1" means $t \leq 1$, which includes 1. The interval is $(-4, 1]$, choice D. For example, 1 belongs to the set and -4 does not.

Signed numbers and order of operations

If an account contains 6 dollars and a charge removes 9 dollars, the balance is $6 - 9 = -3$ dollars. Negative numbers describe positions below a chosen zero. You can add them by tracking direction on a number line rather than trying to memorize a separate rule for every appearance of a minus sign.

Adding and subtracting signed numbers

Adding a positive number moves right. Adding a negative number moves left. Starting at -4 and adding 7 gives 3 because the first 4 units reach zero and the remaining 3 move to its right.



The arrow begins at -4 and ends at 3. The seven unit intervals show the positive change. For $-4 + (-7)$, both movements are left, giving -11.

Numbers with the same sign combine their sizes and keep that sign. With opposite signs, subtract the smaller size from the larger and keep the sign of the number with the larger size: $8 + (-13) = -5$. Here the negative movement exceeds the positive one by 5.

Subtracting a number adds its opposite. Thus $5 - (-3) = 5 + 3 = 8$, whereas $5 - 3 = 2$. Rewrite a difficult subtraction before calculating: $-6 - (-10) = -6 + 10 = 4$. Parentheses make it clear whether a minus sign belongs to a number or tells you to subtract an entire expression.

Products, quotients and signs

Multiplying numbers with opposite signs gives a negative product. Two negative factors give a positive product. You can see why by extending a consistent pattern: $(-3)(2) = -6$, $(-3)(1) = -3$, $(-3)(0) = 0$, and $(-3)(-1) = 3$. Each decrease of 1 in the second factor increases the product by 3.

For several nonzero factors, an even number of negative factors gives a positive product and an odd number gives a negative product. Division follows the same sign rules. Since $(-4)(3) = -12$, $\frac{-12}{3} = -4$. Division by zero is undefined. Zero divided by a nonzero number is zero.

Choosing the order of calculation

A number next to parentheses means multiplication: $2(3) = 2 \times 3 = 6$. Two parentheses next to one another also mean multiply their values. Grouping symbols tell you what to calculate together. Work inside parentheses first, then evaluate exponents. Multiply and divide from left to right. Finally add and subtract from left to right. Multiplication and division have equal priority, as do addition and subtraction. In $18 \div 3 \times 2$, the quotient $18 \div 3 = 6$ comes first, then $6 \times 2 = 12$.

An exponent applies to its base. In $(-3)^2$, the parentheses make -3 the base, so $(-3)(-3) = 9$. In -3^2, the exponent applies to 3 and the leading negative remains outside: $-(3^2) = -9$. These expressions have different values.

A fraction bar groups the whole numerator and the whole denominator. In $\frac{12-4}{2+2}$, first calculate 8 above and 4 below, giving 2. You cannot treat the expression as $12 - \frac{4}{2} + 2$. When substituting a negative value, put it in parentheses so both its sign and the operation remain visible. For $2x^2 - 3x$ at $x = -2$, write $2(-2)^2 - 3(-2) = 8 + 6 = 14$.

Work one operation at a time if several signs occur together. Writing the intermediate line is useful when a calculator display conceals whether the negative sign was inside an exponent.

ACT-Style Question

What is the value of $-3^2 + 2(-4 + 7)$?

A. -15

B. -3

C. 3

D. 15

The exponent applies to 3, so $-3^2 = -9$. Inside the parentheses, $-4+7 = 3$, and $2(3) = 6$. The expression is $-9 + 6 = -3$, choice B. Using $(-3)^2$ would change the original expression and lead to 15.

Chapter 1 Test Preparation

Choose the best answer to each question. A permitted calculator may be used. Figures are not necessarily drawn to scale.

42. Which of the following numbers is greatest?

☐ F. $-\sqrt{5}$ ☐ G. -2.3

☐ H. $-\frac{9}{4}$ ☐ J. -2.2

43. What is the value of $18 - 3(2-5)^2$?

☐ A. -63 ☐ B. -9

☐ C. 27 ☐ D. 45

44. Two warning lights flash together at 9:00 a.m. One flashes every 18 seconds and the other every 24 seconds. How many seconds after 9:00 a.m. will they next flash together?

☐ F. 6 ☐ G. 42

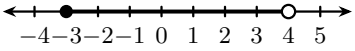
☐ H. 72 ☐ J. 432

45. Which of the following numbers is irrational?

☐ A. $\sqrt{49}$ ☐ B. $\sqrt{18} - \sqrt{2}$

☐ C. $\sqrt{3} \cdot \sqrt{12}$ ☐ D. $\frac{\sqrt{75}}{\sqrt{3}}$

46. The heavy segment on the number line shows all permitted values of x. The left endpoint is filled and the right endpoint is open. Which inequality describes these values?



☐ F. $-3 < x < 4$ ☐ G. $-3 < x \leq 4$

☐ H. $-3 \leq x < 4$ ☐ J. $-3 \leq x \leq 4$

47. When a positive integer n is divided by 7, the remainder is 5. What is the remainder when $3n + 4$ is divided by 7?

☐ A. 1 ☐ B. 4

☐ C. 5 ☐ D. 6

48. A rectangular sheet is 84 centimeters long and 60 centimeters wide. It is cut into congruent square pieces with no material left over. What is the greatest possible side length, in centimeters, of each square?

☐ F. 6 ☐ G. 12

☐ H. 24 ☐ J. 420

49. How many integers n satisfy both $|n-2| < 5$ and $\frac{n}{3}$ is an integer?

☐ A. 2 ☐ B. 3

☐ C. 4 ☐ D. 5

50. The digits 4, 7, 2, 9, and 1 are written in that order and then repeated without end: $4729147291\ldots$. What is the sum of the 203rd and 204th digits?

☐ F. 7 ☐ G. 9

☐ H. 10 ☐ J. 11

51. What is the least positive integer k for which $180k$ is the square of an integer?

☐ A. 2 ☐ B. 5

☐ C. 10 ☐ D. 45

Explanations: page 376.

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Answers

1. $-4 < -\frac{3}{2} < -0.5 < 0.2$ **2.** $[-1, 3)$ **3.** $2 < x \leq 7$ **4.** $-2, -1, 0, 1, 2$ **5.** $5 < \sqrt{31} < 6$ **6.** $(-\infty, 0) \cup [4, \infty)$ **7.** -1 **8.** 9 **9.** -30 **10.** 12 **11.** $-5^2 = -25$; $(-5)^2 = 25$ **12.** -1 **13.** 21 **14.** 5 **15.** -7 **16.** 7 **17.** $x = -1$ or $x = 7$ **18.** $-3 \leq x \leq 1$ **19.** $x < -1$ or $x > 5$ **20.** 0 real solutions **21.** $1, 2, 3, 5, 6, 10, 15, 30$ **22.** Neither; 1 has only one positive factor. **23.** $2^2 \cdot 3^2 \cdot 5$ **24.** GCF $= 6$; LCM $= 72$ **25.** 60 seconds **26.** $d = 5$ **27.** Quotient 8; remainder 2 **28.** $10, 14, 18, 22$ **29.** Even; n and $n + 3$ have opposite parity. **30.** 2 **31.** Q **32.** 2 **33.** 5 **34.** Rational: $\sqrt{81} = 9$. **35.** Irrational. **36.** Rational: $\frac{11}{7}$. **37.** For example, $\sqrt{3}$ and $-\sqrt{3}$ (sum 0). **38.** For example, $\sqrt{2}$ and $\sqrt{2}$ (sum $2\sqrt{2}$). **39.** 0 is rational, and its product with any irrational number is rational 0. **40.** Irrational; subtracting rational 4 from a rational sum would make $\sqrt{5}$ rational. **41.** Irrational; the growing runs of 2s prevent eventual repetition. **42.** J. -2.2 **43.** B. -9 **44.** H. 72 **45.** B. $\sqrt{18} - \sqrt{2}$ **46.** H. $-3 \leq x < 4$ **47.** C. 5 **48.** G. 12 **49.** B. 3 **50.** J. 11 **51.** B. 5

2. Fractions, Decimals, and Percentages

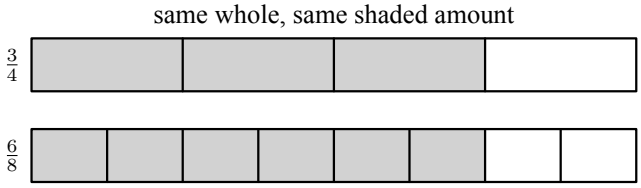
Equivalent Fractions and Mixed Numbers

If a sandwich is cut into four equal pieces and you take three, you have $\frac{3}{4}$ of the sandwich. The denominator, 4, tells how many equal parts make one whole. The numerator, 3, counts the parts taken. The pieces must be equal, and the whole must stay the same when you compare fractions. Half of a large pizza can be more food than half of a small pizza.

A fraction also means division: $\frac{a}{b}$ is the result of dividing a by b. Its denominator cannot be zero. The fraction $\frac{0}{3}$ equals zero, while $\frac{3}{0}$ is undefined. A negative sign can go in front of the fraction, in its numerator, or in its denominator: $-\frac{2}{5} = \frac{-2}{5} = \frac{2}{-5}$. Two negative signs give a positive value, so $\frac{-2}{-5} = \frac{2}{5}$.

Changing the pieces without changing the amount

Cut each quarter of the sandwich into two equal pieces. The three quarters become six eighths. The amount of sandwich stays unchanged: $\frac{3}{4} = \frac{6}{8}$.



The bars have equal total length. The same shaded length covers three quarters or six eighths. In symbols, multiply the numerator and denominator by the same nonzero number. For example, $\frac{5}{7} = \frac{5 \cdot 3}{7 \cdot 3} = \frac{15}{21}$. This works because the multiplier $\frac{3}{3}$ equals 1.

Simplifying reverses that process. Divide the numerator and denominator by a common factor. In $\frac{18}{24}$, both numbers are divisible by 6, giving $\frac{3}{4}$. No integer greater than 1 divides both 3 and 4, so the result is in lowest terms. You can divide in stages if a common factor is easier to spot: $\frac{18}{24} = \frac{9}{12} = \frac{3}{4}$. Both routes preserve the value. You may cancel common factors, but you cannot erase digits or cancel terms joined by addition.

Equivalent fractions can answer a missing-number question. If $\frac{7}{12} = \frac{n}{60}$, the denominator has been multiplied by 5. Multiply the numerator by 5 as well, so $n = 35$. Another check is cross multiplication: equality of $\frac{a}{b}$ and $\frac{c}{d}$ with nonzero denominators gives $ad = bc$. This follows by multiplying both sides by bd.

Improper fractions and mixed numbers

A positive proper fraction is less than 1. For a positive fraction with a positive denominator, an improper fraction has a numerator at least as large as its denominator. For a negative fraction, classify its magnitude in the same way. The fraction

$\frac{17}{5}$ contains three whole groups of five fifths, with two fifths left. Thus $\frac{17}{5} = 3\frac{2}{5}$. Divide to find the whole-number part, then place the remainder over the original denominator.

For the reverse conversion, count all the fractional pieces. In $3\frac{2}{5}$, each whole contributes five fifths. The three wholes contribute 15 fifths, and the additional two fifths give $\frac{3(5)+2}{5} = \frac{17}{5}$. A mixed number represents addition, not multiplication. For a negative mixed number, the sign applies to the entire amount: $-2\frac{1}{3} = -\left(2 + \frac{1}{3}\right) = -\frac{7}{3}$. Converting before calculating helps keep that sign attached.

Comparing fractions

Give fractions a common denominator or compare them to a useful benchmark. For $\frac{5}{8}$ and $\frac{2}{3}$, use twenty-fourths: $\frac{15}{24} < \frac{16}{24}$, so $\frac{5}{8} < \frac{2}{3}$. The denominators alone do not decide which fraction is larger. With the same positive numerator, however, a larger positive denominator means smaller pieces and a smaller fraction. Thus $\frac{3}{7} < \frac{3}{5}$. For negative fractions, the value farther left on the number line is smaller: $-\frac{3}{4} < -\frac{1}{2}$.

In an ACT question, equivalent forms may describe a measurement or distinguish close answer choices. Keep the fraction exact until the question asks for a decimal approximation. A rounded decimal can hide a small difference between two fractions.

ACT-Style Question

A roll of ribbon is $4\frac{3}{8}$ yards long. Which fraction represents this length in yards?

A. $\frac{7}{8}$ **B.** $\frac{3}{2}$

C. $\frac{35}{8}$ **D.** 4

Each yard contains eight eighths. Four yards therefore contain 32 eighths, and the extra three eighths bring the total to 35 eighths. The length is $\frac{4(8)+3}{8} = \frac{35}{8}$ yards, choice C. Dividing 35 by 8 returns 4 with remainder 3, which checks the mixed number. Adding 4 and 3 in the numerator would count four eighths instead of four whole yards.

ACT-Style Question

Which of the following lists the fractions in increasing order?

A. $\frac{5}{8}, \frac{2}{3}, \frac{7}{10}$ **B.** $\frac{2}{3}, \frac{5}{8}, \frac{7}{10}$

C. $\frac{7}{10}, \frac{2}{3}, \frac{5}{8}$ **D.** $\frac{5}{8}, \frac{7}{10}, \frac{2}{3}$

A common denominator of 120 makes the comparison exact. The fractions become $\frac{75}{120}$, $\frac{80}{120}$, and $\frac{84}{120}$. Their numerators increase in that order, so $\frac{5}{8} < \frac{2}{3} < \frac{7}{10}$, choice A. Comparing 5, 2, and 7 by themselves would ignore that the pieces have different sizes.

Adding and Subtracting Fractions

Three eighths of a mile plus two eighths of a mile makes five eighths of a mile. The pieces have the same size, so add the counts: $\frac{3}{8} + \frac{2}{8} = \frac{5}{8}$. Keep the denominator. Adding it would change eighths into sixteenths and give the wrong distance. Subtraction follows the same idea: $\frac{7}{8} - \frac{3}{8} = \frac{4}{8} = \frac{1}{2}$.

Making the units match

To add $\frac{1}{3}$ and $\frac{1}{4}$, first express both amounts using pieces of the same size. Twelfths work because both 3 and 4 divide 12. Replace $\frac{1}{3}$ with $\frac{4}{12}$ and $\frac{1}{4}$ with $\frac{3}{12}$. Now the sum is $\frac{7}{12}$.