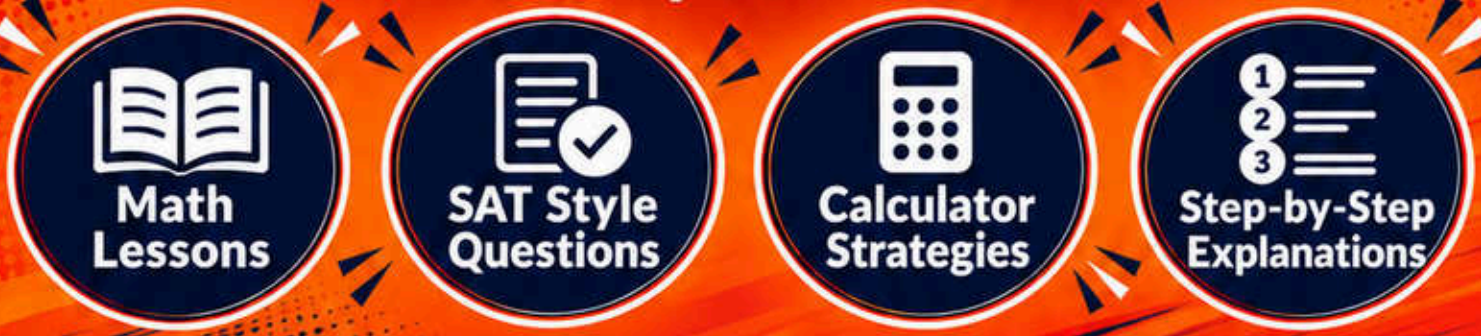
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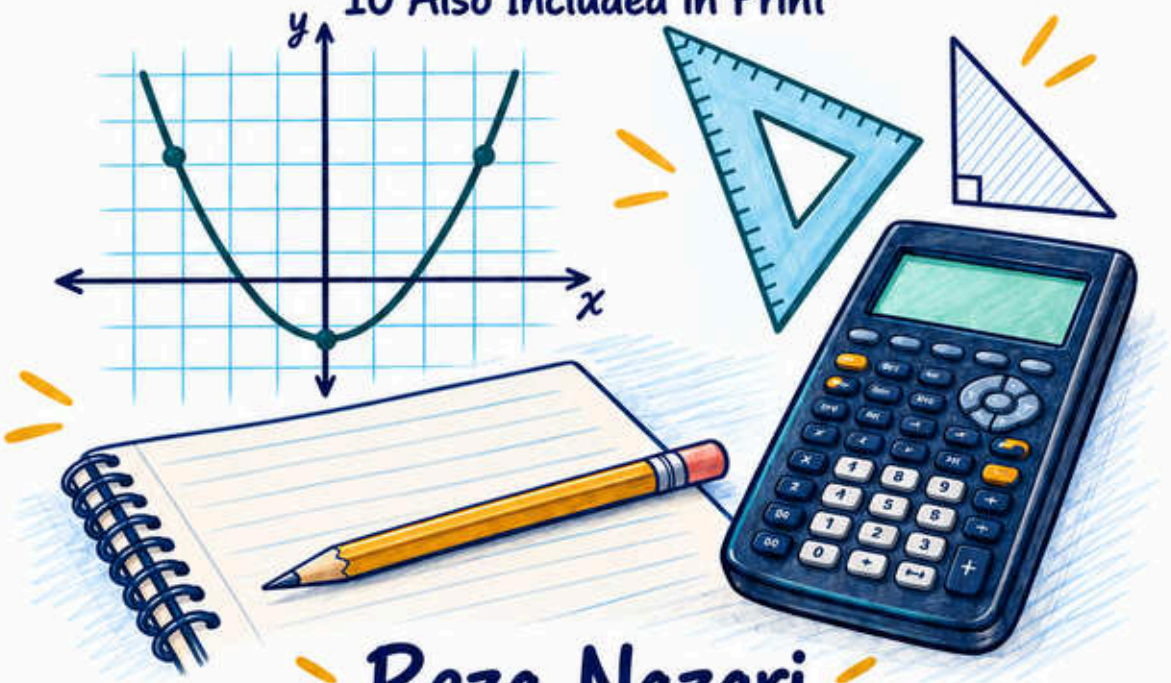
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Reza Nazari

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1. Numbers, Fractions, Powers, and Roots

Fractions, negative signs, and powers appear throughout SAT Math, often inside a longer problem. A small arithmetic error can make a sound method look wrong. Here you can work with those operations on their own and see what each symbol tells you to do.

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 are $0, 1, 2, 3, \ldots$. 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.

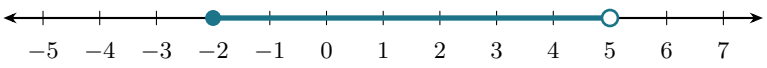
Comparing positions

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.

A rule can change the endpoints of an interval. Suppose $-1 \leq x < 2$ and $y = 3x + 1$. Multiplying every part by positive 3 gives $-3 \leq 3x < 6$; adding 1 throughout gives $-2 \leq y < 7$. The multiplier is positive, so the inequality directions stay the same. The lower endpoint remains included and the upper endpoint remains excluded. Thus the possible values of y form $[-2, 7)$.

SAT Style Question

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

A. 6

B. 5

C. 7

D. 4

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 A. The strict lower inequality still allows -3 because -3 is greater than $-\sqrt{10}$.

SAT Style Question

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

A. $-4 < t < 1$

B. $-4 \leq t \leq 1$

C. $-4 \leq t < 1$

D. $-4 < t \leq 1$

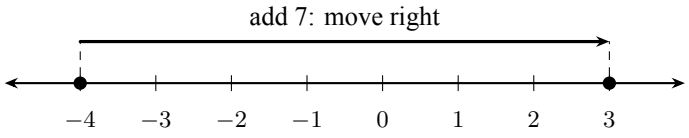
Greater than -4 means $t > -4$, so -4 is excluded. At most 1 means $t \leq 1$, so 1 is included. Combining the conditions gives $-4 < t \leq 1$, choice D. For example, 1 meets both conditions, while -4 does not.

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 are less than zero. On a horizontal number line, they lie to the left of zero. A negative account balance represents an amount below 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

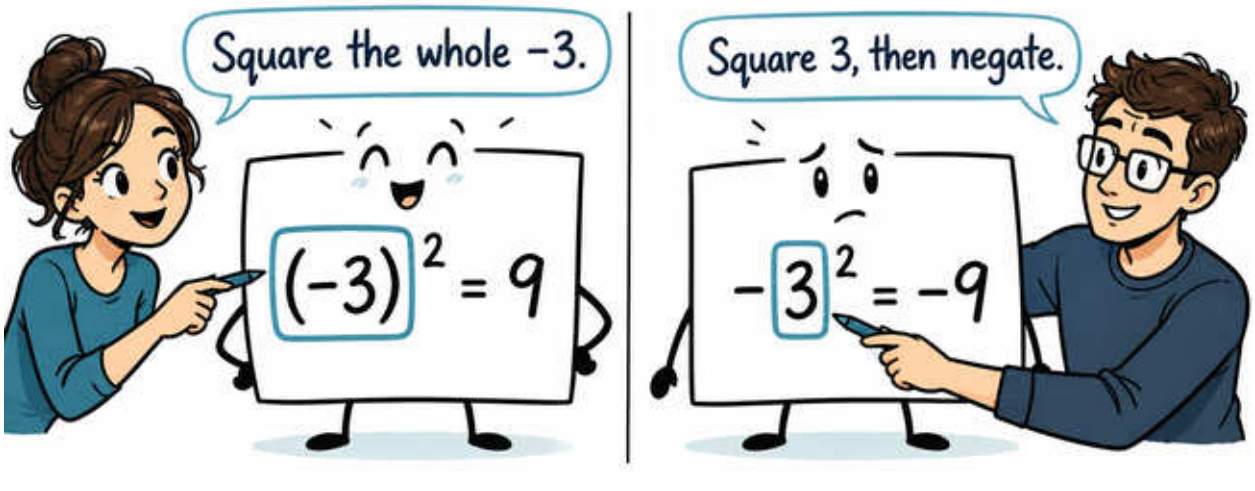
Multiplying numbers with opposite signs gives a negative product. Two negative factors give a positive product. You can see why by extending a consistent pattern: $(-3)(2) = -6$, $(-3)(1) = -3$, $(-3)(0) = 0$, and $(-3)(-1) = 3$. Each decrease of 1 in the second factor increases the product by 3.

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 entire numerator and denominator. In $\frac{12-4}{2+2}$, calculate $12-4=8$ above the bar and $2+2=4$ below it, giving $\frac{8}{4}=2$. Writing $12-\frac{4}{2}+2$ changes what is divided.

The notation $f(a)$ means the value of a function at input a; it does not mean f multiplied by a. If $f(x) = 2x^2 - 3x$, then $f(-2)$ means replace every x with -2. Use parentheses around the negative input: $f(-2) = 2(-2)^2 - 3(-2)$. Since $(-2)^2 = 4$ and $-3(-2) = 6$, the value is $2(4) + 6 = 14$.

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.

SAT Style Question

The function f is defined by $f(x) = -x^2 + 2x$. What is the value of $f(3)$?

A. 3 **B.** 15

C. -15 **D.** -3

Replace each x with 3: $f(3) = -(3^2) + 2(3) = -9 + 6 = -3$, choice D. The minus sign is outside the square, so the first term is negative. Squaring -3 instead would change the function and give the incorrect result 15.

The pizzas use equal-sized wholes divided into twelfths. Four pieces and three pieces combine to give seven pieces of that same size. Each replacement multiplies the numerator and denominator by the same number, so it preserves the original amount.

A common denominator is any positive common multiple of the denominators. The least common denominator is their least positive common multiple. With denominators 6 and 8, the least common denominator is 24. Their product, 48, also works, but it leaves more simplification. List multiples when the numbers are small. For larger numbers, factor them and include each prime factor as many times as either denominator needs it. Since $12 = 2^2 \cdot 3$ and $18 = 2 \cdot 3^2$, their least common multiple is $2^2 \cdot 3^2 = 36$.

For example, $\frac{5}{12} - \frac{1}{18} = \frac{15}{36} - \frac{2}{36} = \frac{13}{36}$. Write both equivalent fractions before subtracting if you tend to lose the multiplier. Subtracting the denominators, or changing a denominator without changing its numerator, changes the problem.

Signs and mixed numbers

A signed fraction follows the same addition rules as a signed integer. In $-\frac{2}{3} + \frac{1}{4}$, use twelfths to get $-\frac{8}{12} + \frac{3}{12} = -\frac{5}{12}$. The negative amount has greater magnitude. Subtracting a negative reverses its direction: $\frac{1}{6} - \left(-\frac{1}{4}\right) = \frac{1}{6} + \frac{1}{4} = \frac{5}{12}$. Keep parentheses around a negative fraction until the subtraction sign has been handled.

Mixed numbers can be converted to improper fractions before calculation. For $2\frac{1}{6} - 1\frac{3}{4}$, the conversion gives $\frac{13}{6} - \frac{7}{4} = \frac{26}{12} - \frac{21}{12} = \frac{5}{12}$. This route works even when the fractional part of the first mixed number is too small to subtract the second fractional part.

You can also regroup one whole. Write $2\frac{1}{6} = 1\frac{7}{6}$, then subtract the one whole and $\frac{3}{4}$ from $1 + \frac{7}{6}$. The remaining fractional difference is $\frac{14}{12} - \frac{9}{12} = \frac{5}{12}$. Choose the approach whose signs and pieces you can track reliably. For several terms, a single common denominator keeps the arithmetic together: $\frac{1}{2} + \frac{1}{3} - \frac{1}{4} = \frac{6}{12} + \frac{4}{12} - \frac{3}{12} = \frac{7}{12}$.

Fractions with letters and fractions in context

A letter can stand for an unknown number. In $3x$, the 3 tells you to multiply x by 3. Three copies of x minus two copies leave one copy: $3x - 2x = x$. Multiplying a sum by 3 multiplies each term, so $3(x - 1) = 3x - 3$. A negative multiplier also applies to each term: $-2(x + 2) = -2x - 4$. You can check this last equality at $x = 1$: both expressions give -6. These rules let you handle an entire numerator without losing a sign.

The same rule applies when a numerator contains a letter. For $\frac{x}{3} + \frac{x}{5}$, use fifteenths: $\frac{5x}{15} + \frac{3x}{15} = \frac{8x}{15}$. This is true for every real x. If the denominator contains a variable, state its restrictions. For example, $\frac{1}{x} + \frac{2}{3x} = \frac{3}{3x} + \frac{2}{3x} = \frac{5}{3x}$ requires $x \neq 0$. The fraction cannot be evaluated at zero before or after simplification.

In a word problem, identify the whole and the measurement unit before adding. Fractions of one tank can be added as fractions of that tank. A fraction of a tank and a number of liters need a conversion first. Estimate the result too. A sum of two positive fractions must be greater than either fraction, while subtracting a positive amount must reduce the starting value.

SAT Style Question

A student spends $\frac{3}{8}$ hour reading and $\frac{5}{12}$ hour writing. What is the total time, in minutes?

A. 22.5

B. 47.5

C. 24

D. 25

Add the two times using a denominator of 24: $\frac{3}{8} + \frac{5}{12} = \frac{9}{24} + \frac{10}{24} = \frac{19}{24}$ hour. An hour contains 60 minutes, so the total is $(\frac{19}{24})(60) = 47.5$ minutes, choice B. Both fractions describe hours; the multiplication by 60 converts the combined time to the requested unit.

SAT Style Question

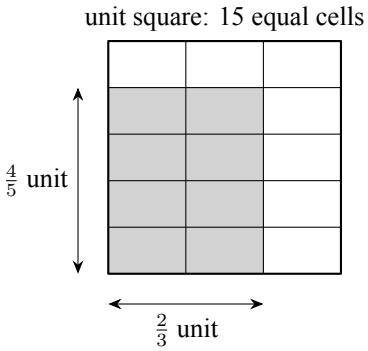
For every real number x, which expression is equivalent to $\frac{x-1}{4} - \frac{x+2}{6}$?

A. $\frac{x-7}{12}$ **B.** $\frac{x+1}{12}$

C. $\frac{-3}{2}$ **D.** $\frac{5x+1}{12}$

Use a denominator of 12. The first numerator becomes $3(x-1)$ and the second becomes $2(x+2)$, giving $\frac{3(x-1)-2(x+2)}{12}$. Multiply each term inside the parentheses: $3(x-1) = 3x-3$ and $-2(x+2) = -2x-4$. Combine the three copies of x minus two copies, then combine the constants: $3x-3-2x-4 = x-7$. The result is $\frac{x-7}{12}$, choice A. At $x = 0$, the original expression is $-\frac{1}{4} - \frac{1}{3} = -\frac{7}{12}$, agreeing with this result.

Multiplying and dividing fractions



Half of three fourths is three eighths. You can see this by dividing each fourth into two equal pieces: $\frac{1}{2} \cdot \frac{3}{4} = \frac{3}{8}$. Multiplication finds a fraction of an amount. If a rectangle has side lengths $\frac{2}{3}$ unit and $\frac{4}{5}$ unit, dividing a unit square into three columns and five rows gives fifteen equal small rectangles. Select two of the three columns and four of the five rows. Their overlap contains $2 \cdot 4 = 8$ of the 15 equal small rectangles, so its area is $\frac{8}{15}$ square units.

The shaded rectangle spans two columns and four rows. Its eight cells each have area $\frac{1}{15}$ square units.

These examples explain the multiplication rule: multiply the numerators and multiply the denominators, then simplify. Thus $\frac{a}{b} \cdot \frac{c}{d} = \frac{ac}{bd}$ when b and d are nonzero. A whole number can be written over 1. For example, $6 \cdot \frac{2}{9} = \frac{6}{1} \cdot \frac{2}{9} = \frac{12}{9} = \frac{4}{3}$.

Reducing before multiplying

In $\frac{14}{15} \cdot \frac{25}{21}$, multiplying first gives $\frac{350}{315}$. Smaller numbers are easier to handle. Divide the factors 14 and 21 by 7, and divide 25 and 15 by 5. The product becomes $\frac{2}{3} \cdot \frac{5}{3} = \frac{10}{9}$. Each reduction removes a factor shared by the complete numerator and denominator. You can reduce across the two fractions because their numerators are multiplied together and their denominators are multiplied together.

Cancellation applies to factors. For example, the 3 in $\frac{3+2}{3}$ cannot be canceled with one term of the sum. The numerator is 5, so that fraction equals $\frac{5}{3}$. Treat a sum in parentheses as a complete quantity until you have evaluated or factored it.

Convert mixed numbers before multiplication. In $1\frac{1}{2} \cdot 2\frac{2}{3}$, use $\frac{3}{2} \cdot \frac{8}{3} = 4$. Multiplying the whole parts and fractional parts separately would omit contributions. Signed multiplication follows the integer rules: two negative factors give a positive result, while one negative factor gives a negative result. Consequently $-\frac{3}{5} \cdot \frac{10}{9} = -\frac{2}{3}$.

Division counts groups

How many quarter-liter servings fit in $\frac{3}{2}$ liters? Each liter contains four quarters, so one and a half liters contains six quarters. This is the division $\frac{3}{2} \div \frac{1}{4} = 6$. Division can also describe sharing: $\frac{3}{4} \div 3 = \frac{1}{4}$ gives the amount each person receives when three people share $\frac{3}{4}$ of a pizza equally.

The reciprocal of a nonzero number is the number that multiplies with it to give 1. The reciprocal of $\frac{c}{d}$ is $\frac{d}{c}$, provided both c and d are nonzero. Dividing by $\frac{c}{d}$ means multiplying by its reciprocal: $\frac{a}{b} \div \frac{c}{d} = \frac{a}{b} \cdot \frac{d}{c}$. To see why, call the quotient q. The equation $q \cdot \frac{c}{d} = \frac{a}{b}$ becomes $q = \frac{a}{b} \cdot \frac{d}{c}$ after both sides are multiplied by $\frac{d}{c}$.

Only the divisor is inverted. In $\frac{5}{6} \div \frac{10}{9}$, keep $\frac{5}{6}$ and multiply by $\frac{9}{10}$ to obtain $\frac{3}{4}$. Dividing by zero is undefined because zero has no reciprocal. Zero divided by a nonzero number is zero.

Nested fractions and reasonable results

A fraction bar already means division. The expression $\frac{\frac{2}{3}}{\frac{5}{6}}$ equals $\frac{2}{3} \div \frac{5}{6} = \frac{2}{3} \cdot \frac{6}{5} = \frac{4}{5}$. If the numerator or denominator contains addition, perform that addition first. For $\frac{\frac{1}{2}+\frac{1}{3}}{\frac{5}{6}}$, the numerator is $\frac{5}{6}$, so the entire fraction equals 1.

Multiplying a positive amount by a fraction between 0 and 1 makes it smaller. Dividing by such a fraction makes it larger because smaller groups fit more times. These comparisons help check your calculations. In a serving or cutting problem, also distinguish the numerical quotient from the number of complete groups. A quotient of $6\frac{1}{2}$ means six full groups and half of another, so only six complete groups fit.

SAT Style Question

A bottle contains $2\frac{1}{4}$ liters of juice. Each serving uses $\frac{3}{8}$ liter. How many full servings can be poured?

A. 5 **B.** 8

C. 6 **D.** 3

Divide the available juice by the amount in one serving. Since $2\frac{1}{4} = \frac{9}{4}$, the count is $\frac{9}{4} \div \frac{3}{8} = \frac{9}{4} \cdot \frac{8}{3} = 6$, choice C. Reducing 8 with 4 and 9 with 3 makes the multiplication smaller. Six servings use $6 \cdot \frac{3}{8} = \frac{18}{8} = \frac{9}{4}$ liters, so all the juice is accounted for.

SAT Style Question

Of the students at a school, $\frac{3}{5}$ participate in a sport. Of those who participate in a sport, $\frac{7}{12}$ play a team sport. What fraction of all students participate in a sport but do not play a team sport?

Within the sports group, the fraction who do not play a team sport is $1 - \frac{7}{12} = \frac{5}{12}$. Multiply by the fraction of the whole school in sports: $\frac{3}{5} \cdot \frac{5}{12} = \frac{1}{4}$. Enter `1/4` or `0.25`. The fraction $\frac{5}{12}$ alone uses only the sports group as its reference; multiplying by $\frac{3}{5}$ relates the answer to the whole school.

Decimals, place value, rounding, and estimation

The number 4.37 means four wholes, three tenths, and seven hundredths. Each position has one tenth the value of the position immediately to its left. Moving right from the decimal point gives tenths, hundredths, thousandths, and ten-thousandths. Thus $0.064 = \frac{6}{100} + \frac{4}{1000} = \frac{64}{1000}$.

Zeros can mark positions without adding value. The decimals 0.6, 0.60, and 0.600 are equal. In 0.06, however, the zero in the tenths position moves the 6 into the hundredths position. That value is one tenth of 0.6. To compare positive decimals, align their decimal points and add trailing zeros: $0.47 = 0.470 < 0.506$. Compare from left to right until the first differing digit appears. For negatives, reverse the magnitude comparison. Since $0.506 > 0.470$, we have $-0.506 < -0.470$.

Calculating with decimals

For addition and subtraction, line up decimal points so that hundredths combine with hundredths and tenths with tenths. In $3.4 - 0.87$, write $3.40 - 0.87$. To subtract 7 hundredths from zero hundredths, regroup one tenth as 10 hundredths. Then regroup one whole as 10 tenths so there are enough tenths to subtract 8. The top amount is now 2 wholes, 13 tenths and 10 hundredths. Subtracting 0 wholes, 8 tenths and 7 hundredths leaves 2 wholes, 5 tenths and 3 hundredths, or 2.53. Regrouping preserves the total amount, and the added trailing zero preserves the original value 3.4.