

**Check-In 01/15.** (*True/False*) The relation given by  $f(x) = \frac{x+6}{3x-5}$  is a function.

**Solution.** The statement is *true*. For each input  $x$ , there is only one possible output—namely, the one obtained by plugging in the given  $x$ -value and following order of operations. For instance, given  $x = 2$ , we have...

$$f(2) = \frac{2+6}{3(2)-5} = \frac{8}{6-5} = \frac{8}{1} = 8$$

**Check-In 01/16.** (*True/False*) Suppose Didly is trying to predict the amount of prison years that he will receive for the number of crimes that he has (allegedly) committed. The number of years would be the independent variable, the number of crimes would be the dependent variable, and the number of years is a function of the number of crimes.

**Solution.** The statement is *false*. Didly is trying to predict the number of years in prison. This must be the output of his ‘model’, i.e. function. Therefore, it must be that the number of years in prison is the dependent variable. Because he is trying to make the prediction using the number of crimes, i.e. use this as the input to his model, the number of crimes must be the independent variable. However, it is true that the number of years should be a function of the number of crimes because Didly can only be sentenced to one possible number of years given the number of crimes that he has committed.

**Check-In 01/21.** (*True/False*) The equation  $\frac{2x-6}{2}$  is equivalent to  $x-6$ .

**Solution.** The statement is *false*. First,  $\frac{2x-6}{2}$  is not an equation—nor is  $x-6$  an equation. The statement should read, “The expression  $\frac{2x-6}{2}$  is equivalent to  $x-6$ .” However, these expressions still are not equivalent. If the expressions are equivalent, then they yield the same value for *every* valid  $x$ -value. If we substitute  $x = 1$  into each expression, we have...

$$\begin{aligned} \left. \frac{2x-6}{2} \right|_{x=1} &= \frac{2(1)-6}{2} = \frac{2-6}{2} = \frac{-4}{2} = -2 \\ \left. x-6 \right|_{x=1} &= 1-6 = -5 \end{aligned}$$

Because these are not the same, these expressions cannot be equivalent.

**Check-In 01/22.** (*True/False*) If the line  $y = a$  intersects the graph of  $f(x)$ , then there *must* be a solution to the equation  $f(x) = a$ .

**Solution.** The statement is *true*. If the graph of  $f(x)$  and the line  $y = a$  intersect, then there is a point  $(x_0, y_0)$  on the graph of both. But each point on the graph of  $f(x)$  has the property that  $y = f(x)$  so that  $y_0 = f(x_0)$ . But because this point also lies along the line  $y = a$ , we know that

$y_0 = a$ . Then  $f(x_0) = y_0 = a$ , i.e.  $f(x_0) = a$ . Therefore, there is at least one  $x$ -value such that  $f(x) = a$ —namely,  $x = x_0$ .

**Check-In 01/23.** (True/False) If  $(-1, 3)$  and  $(5, -2)$  are points on the graph of  $f(x)$ , then the average rate of change for  $f(x)$  on  $[-1, 5]$  is  $-\frac{2}{3}$ .

**Solution.** The statement is *false*. The average rate of change for a function  $f(x)$  on an interval  $[a, b]$  is  $\frac{f(b)-f(a)}{b-a}$ , i.e. the slope of the line segment through the points  $(a, f(a))$  and  $(b, f(b))$ . But then the average rate of change for this function is...

$$\text{Avg. ROC} = \frac{3 - (-2)}{-1 - 5} = \frac{5}{-6} = -\frac{5}{6}$$

**Check-In 01/28.** (True/False) Functions that have a constant rate of change must be linear.

**Solution.** The statement is *true*. A function being linear is equivalent to any of the following: it has a constant rate of change, it can be expressed as  $y = mx + b$  for some  $m, b$ , and its graph is a line. To see why a function with a constant rate of change must be linear, suppose the value at  $x = 0$  is 5. Suppose the constant rate of change for each increase of 1 in  $x$  is  $-4$ , i.e. every increase of 1 in  $x$  results in a decrease of 4 in the output. At  $x = 1$ , we know  $y = 5 - 4 = 1$ . At  $x = 2$ , we know that  $y = 5 - 4 - 4 = 5 - 4(2) = -3$ . At  $x = 3$ , we know that  $y = 5 - 4 - 4 - 4 = 5 - 4(3) = -7$ . Generally, given  $x$ , we can see that  $y = 5 - 4x$ . Letting  $m = -4$  and  $b = 5$ , we can see that  $y = mx + b$ . But nothing is special about the choice of 5 for the ‘starting’ value or  $m = -4$  for the rate of change—this would merely change the numbers. Therefore, any linear function should be expressible as  $y = mx + b$ .

**Check-In 01/28.** (True/False) If  $\ell(x) = \frac{6x - 12}{-2}$ , then  $\ell$  is linear with slope  $-3$  and  $y$ -intercept 6.

**Solution.** The statement is *true*. Observe that  $\ell(x) = \frac{6x - 12}{-2} = \frac{6x}{-2} - \frac{12}{-2} = -3x - (-6) = -3x + 6$ . Observe that  $\ell(x)$  has the form  $y = mx + b$  with  $y = \ell$ ,  $m = -3$ ,  $x = x$ , and  $b = 6$ . Because  $\ell(x)$  has the form  $y = mx + b$ ,  $\ell(x)$  must be linear. We know also that the slope is  $m = -3$  and the  $y$ -intercept is  $b = 6$ .

**Check-In 01/29.** (True/False) If a line has slope 8 and contains the point  $(1, 5)$ , then the equation of the line is  $y = 5 + 8(x + 1)$ .

**Solution.** The statement is *false*. There are many ways to determine this. For instance, recall the point-slope form of a line: if a line has slope  $m$  and contains a point  $(x_0, y_0)$ , then the equation for the line is  $y = y_0 + m(x - x_0)$ . We know the line has slope 8 and contains  $(1, 5)$ ; therefore, the equation of the line must be  $y = y_0 + m(x - x_0) = 5 + 8(x - 1)$ , which is not the given line.

Therefore, the statement is false. Alternatively, if a line contains a point, that point must satisfy the equation of the line. So, if  $(1, 5)$  is on the given line, then  $y = 5$  when  $x = 1$ . However, when  $x = 1$ , we can see that  $y = 5 + 8(1 + 1) = 5 + 8(2) = 5 + 16 = 21$ , which is not 5. Therefore, the statement is false.

**Check-In 01/30.** (*True/False*) The line  $y = 5 - 3(x + 2)$  has slope  $-3$  and contains the point  $(-2, 5)$ .

**Solution.** The statement is *true*. There are many ways to determine this. For instance, recall the point-slope form of a line: if a line has slope  $m$  and contains a point  $(x_0, y_0)$ , then the equation for the line is  $y = y_0 + m(x - x_0)$ . We know that if the line had slope  $-3$  and contained the point  $(-2, 5)$ , the equation of the line would be  $y = y_0 + m(x - x_0) = 5 + (-3)(x - (-2)) = 5 - 3(x + 2)$ , which is the given line. Therefore, the statement is true. Alternatively, we have  $y = 5 - 3(x + 2) = 5 - 3x - 6 = -3x - 1$ . We can see that the line has slope  $m = -3$ . If the line contains the point  $(-2, 5)$ , then it satisfies the equation of the line. So, if  $x = -2$ , we know that  $y = 5$ . Observe that when  $x = -2$ , we have  $y = -3(-2) - 1 = 6 - 1 = 5$ . Therefore, the statement is true.

**Check-In 02/03.** (*True/False*) The average rate of change for a linear function is its slope.

**Solution.** The statement is *true*. We know that the rate of change of a linear function is its slope,  $m$ . This rate of change is constant because the function is linear. But then computing the average rate of change for a linear function must always be the same—the value of  $m$ .

**Check-In 02/04.** (*True/False*) It is possible for lines to be both parallel and perpendicular.

**Solution.** The statement is *false*. This is best thought about geometrically. Although we know that two linear functions are parallel if and only if their slopes are equal, geometrically, this means that the lines never intersect. Furthermore, while we know two linear functions are perpendicular if and only if their slopes are negative reciprocals, geometrically, this means that the lines intersect at right angles. But then if lines are parallel, they cannot intersect. But if they are perpendicular, they must intersect (at right angles). So, lines cannot be both parallel and perpendicular.

**Check-In 02/05.** (*True/False*) If Carroll and John each begin with different amounts of Cesium-137 that decay linearly at equal rates, then Carroll and John will never have the same amount of Cesium-137.

**Solution.** The statement is *true*. We are told that the amount of Cesium-137 both Carroll and John have is given by a linear function (because we are told they decay linearly). But because the Cesium-137 for both individuals decays at the same rate, the slopes (rates of change) for these linear functions must be equal. But then if the lines are distinct, they must be parallel. But we know Carroll and John start with different amounts of Cesium-137; therefore, the amount of Cesium-137 that the linear models say Carroll and John have will never be the same.

**Check-In 02/06.** (*True/False*) A system of two linear equations consists of non-parallel lines, then the system has a solution.

**Solution.** The statement is *true*. We know a solution to a system of equations corresponds to point(s) that lie on the graphs given by each equation. Because the lines are *not* parallel, they must intersect. But this intersection point corresponds to a solution to the system of equations.

**Check-In 02/10.** (*True/False*) It is possible for a system of linear equations to have fifteen solutions.

**Solution.** The statement is *false*. If a system of linear equations is given by lines which are parallel, there are no solutions to the system of equations, i.e. there are no solutions. If a system of linear equations are given by the same line, then *every* point along the line is a solution to the system of equations, i.e. there are infinitely many solutions. If the lines are distinct and non-parallel, then the lines intersect at a single point. This point of intersection is the solution to the system of equations, i.e. there is only one solution. But then a system of linear equations either has none, one, or infinitely many solutions. It is then impossible for there to be any other number of solutions.

**Check-In 02/11.** (*True/False*) There is a solution to . . .

$$\begin{cases} 5x - y = 10 \\ -10x + 2y = -20 \end{cases}$$

**Solution.** The statement is *true*. Observe that taking the first equation and multiplying by  $-2$ , we have  $-10x + 2y = -20$ . Equivalently, dividing the entire second equation by  $-2$ , we have  $5x - y = 10$ . That is, the two equations are the same, i.e. the lines are the same. But then they share *every* point in common. But then any point along this line is a solution. The line given by  $5x - y = 10$  is  $y = 5x - 10$ . Therefore, given any  $x$  such that  $y = 5x - 10$  is a solution to the system of equations, e.g.  $(0, -10)$ ,  $(5, 15)$ ,  $(-3, -25)$ , etc. There is then not only a solution but infinitely many solutions.

**Check-In 02/12.** (*True/False*) To find the average rate of change for  $f(x)$  on  $[1, 7]$ , one needs to compute  $\frac{f(1) - f(7)}{1 - 7}$ .

**Solution.** The statement is *true*. Recall that the average rate of change for a function on an interval is the slope of the line through the endpoints of the function on the interval. That is, the average rate of change for  $f(x)$  on  $[a, b]$  is the slope of the line through  $(a, f(a))$  and  $(b, f(b))$ . Therefore, the average rate of change for  $f(x)$  on  $[1, 7]$  is . . .

$$\frac{f(7) - f(1)}{7 - 1} = \frac{f(1) - f(7)}{1 - 7}$$

**Check-In 02/18.** (True/False) The function  $y = 2(x + 1)^2 - 3$  is a quadratic function with  $a = 4$ ,  $b = 4$ , and  $c = -3$ .

**Solution.** The statement is *false*. Observe that...

$$y = 2(x + 1)^2 - 3 = 2(x + 1)(x + 1) - 3 = 2(x^2 + 2x + 1) - 3 = 2x^2 + 4x + 2 - 3 = 2x^2 + 4x - 1$$

Because  $y$  has the form  $ax^2 + bx + c$ , where  $a = 2$ ,  $b = 4$ , and  $c = -1$ , the function is quadratic. However, the given  $a, b, c$  values are incorrect.

**Check-In 02/19.** (True/False) The quadratic function  $y = 5 - (x + 2)^2$  has vertex  $(-2, 5)$  and opens upwards. This implies that  $y$  has a minimum value.

**Solution.** The statement is *false*. The vertex form of a quadratic function is  $f(x) = a(x - P)^2 + Q$ , where  $(P, Q)$  is the location of the vertex. We have  $y = 5 - (x + 2)^2 = -(x + 2)^2 + 5 = -(x - (-2))^2 + 5$  so that  $a = -1$ ,  $P = -2$ , and  $Q = 5$ . Therefore, the vertex of the quadratic function is the point  $(-2, 5)$ . Generally, suppose a quadratic function is written in the form  $y = a(x \pm p)^2 + q$ . The  $y$ -coordinate of the vertex is the constant term and the  $x$ -coordinate of the vertex is the  $x$ -value for which the quadratic term vanishes. So for  $y = 5 - (x + 2)^2$ , the constant term is 5 and the  $x$ -value that makes the quadratic term vanish, i.e. equal 0, is  $x = -2$ . Therefore, the vertex is  $(-2, 5)$ . However, we know that if  $a < 0$ , the quadratic function opens downwards, whereas if  $a > 0$ , the quadratic function opens upwards. Because  $a = -1 < 0$ , this quadratic function opens downwards. This would imply that  $y$  has a maximum value. [If the quadratic function opened upwards, then there would be a minimum  $y$ -value.]

**Check-In 02/20.** (True/False) The function  $f(x) = 2(x + 3)^2 - 12$  has a minimum value, which is 12, and occurs when  $x = 3$ .

**Solution.** The statement is *false*. The vertex form of a quadratic function is  $f(x) = a(x - P)^2 + Q$ , where  $(P, Q)$  is the location of the vertex. We have  $f(x) = 2(x + 3)^2 - 12 = 2(x - (-3))^2 - 12$  so that  $a = 2$ ,  $P = -3$ , and  $Q = -12$ . Because  $a = 2 > 0$ , we know that this quadratic function opens upwards, i.e. is convex. This shows that there is a minimum  $y$ -value. We know this minimum value is the constant term in the vertex form, which here is  $-12$ , and occurs at the  $x$ -coordinate of the vertex, which here is  $x = -3$ . Alternatively, because  $a = 2 > 0$ , this quadratic function opens upwards. This shows that there is a minimum  $y$ -value. Because the function is in vertex form, this minimum value occurs when the 'quadratic term' is 0, which occurs when  $x = -3$ , and then is the remaining value once the 'quadratic term' has vanished, which here is  $-12$ .

**Check-In 02/24.** (True/False) The quadratic formula states that the solutions to  $ax^2 + bx + c = 0$  are  $x = \frac{-b \pm \sqrt{D}}{a}$ , where  $D$  is the discriminant of  $ax^2 + bx + c$ , and is derived from completing the square.

**Solution.** The statement is *false*. The quadratic formula is  $x = \frac{-b \pm \sqrt{D}}{2a}$ , where  $D$  is the discriminant of  $ax^2 + bx + c$ . Recall that  $D = b^2 - 4ac$ . The quadratic formula is derived from completing the square to solve for  $x$  in  $ax^2 + bx + c = 0$ . In fact, we can derive this quickly here: we first make the  $x^2$ -coefficient one:

$$0 = ax^2 + bx + c = a \left( x^2 + \frac{b}{a}x + \frac{c}{a} \right)$$

Half the  $x$ -coefficient is  $\frac{b}{2a}$ , which squaring yields  $(\frac{b^2}{4a^2})$ . Adding and subtracting this term yields...

$$\begin{aligned} 0 &= ax^2 + bx + c \\ &= a \left( x^2 + \frac{b}{a}x + \frac{c}{a} \right) \\ &= a \left( x^2 + \frac{b}{a}x + \frac{b^2}{4a^2} - \frac{b^2}{4a^2} + \frac{c}{a} \right) \\ &= a \left( \left( x^2 + \frac{b}{a}x + \frac{b^2}{4a^2} \right) - \frac{b^2}{4a^2} + \frac{c}{a} \right) \\ &= a \left( \left( x + \frac{b}{2a} \right)^2 - \frac{b^2}{4a^2} + \frac{4ac}{4a^2} \right) \\ &= a \left( \left( x + \frac{b}{2a} \right)^2 + \frac{-b^2 + 4ac}{4a^2} \right) \\ &= a \left( x + \frac{b}{2a} \right)^2 + \frac{-b^2 + 4ac}{4a} \end{aligned}$$

This is just the vertex form of  $ax^2 + bx + c$ . But then solving for the quadratic term, we have...

$$\begin{aligned} 0 &= a \left( x + \frac{b}{2a} \right)^2 + \frac{-b^2 + 4ac}{4a} \\ -a \left( x + \frac{b}{2a} \right)^2 &= \frac{-b^2 + 4ac}{4a} \\ a \left( x + \frac{b}{2a} \right)^2 &= -\frac{-b^2 + 4ac}{4a} \\ a \left( x + \frac{b}{2a} \right)^2 &= \frac{b^2 - 4ac}{4a} \\ \left( x + \frac{b}{2a} \right)^2 &= \frac{b^2 - 4ac}{4a^2} \\ \sqrt{\left( x + \frac{b}{2a} \right)^2} &= \pm \sqrt{\frac{b^2 - 4ac}{4a^2}} \\ x + \frac{b}{2a} &= \pm \frac{\sqrt{b^2 - 4ac}}{2a} \\ x &= -\frac{b}{2a} \pm \frac{\sqrt{b^2 - 4ac}}{2a} \\ x &= \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \end{aligned}$$

**Check-In 02/25.** (True/False) The polynomial  $4 - x^2$  factors as  $-(x - 2)(x + 2)$ .

**Solution.** The statement is *true*. Recall that a difference of perfect squares,  $a^2 - b^2$ , factors as  $(a - b)(a + b)$ . Observe that  $4 - x^2 = -(x^2 - 4)$ . This is a difference of perfect squares with  $a = x$  (so that  $a^2 = x^2$ ) and  $b = 2$  (so that  $b^2 = 4$ ). But then...

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

**Check-In 02/26.** (True/False) Because the polynomial  $x^2 + x - 3$  has discriminant  $D = 13$ , it does not factor but has two distinct, real, not 'nice' roots.

**Solution.** The statement is *true*. The discriminant of a quadratic function  $ax^2 + bx + c$  is  $D = b^2 - 4ac$ . We know a polynomial factors 'nicely' if and only if  $D$  is a perfect square. Furthermore, the polynomial  $ax^2 + bx + c$  has real roots if and only if  $D \geq 0$  (and only two distinct roots if  $D > 0$ ). Finally, the roots of  $ax^2 + bx + c$  are 'nice' if and only if  $D$  is a perfect square. For the polynomial  $x^2 + x - 3$ , we have  $a = 1$ ,  $b = 1$ , and  $c = -3$ . But then...

$$D = b^2 - 4ac = 1^2 - 4(1)(-3) = 1 - (-12) = 1 + 12 = 13$$

We see that  $D > 0$ , so that  $x^2 + x - 3$  has two distinct real roots. Because  $\sqrt{D} = \sqrt{13} \approx 3.60555$  is not a perfect square, the roots of  $x^2 + x - 3$  cannot be 'nice.'

**Check-In 02/27.** (True/False) If  $p(x) = 396x^2 - 18005x + 18000$  has roots  $x = \frac{45}{44}$  and  $x = \frac{400}{9}$ , then  $p(x)$  factors as  $(44x - 45)(9x - 400)$ .

**Solution.** The statement is *true*. We can find the factorization of  $p(x)$  by 'unsolving' for  $x$  once we have the roots:

$$x = \frac{45}{44} \qquad x = \frac{400}{9}$$

$$44x = 45 \quad 9x = 400$$

$$44x - 45 = 0 \quad 9x - 400 = 0$$

Therefore,  $44x - 45$  and  $9x - 400$  are factors of  $p(x)$ . We know that for  $p(x)$ ,  $a = 396$ . But  $44 \cdot 9 = 396$ . Therefore, we must have  $p(x) = (44x - 45)(9x - 400)$ . Alternatively, we know that if  $ax^2 + bx + c$  has roots  $r_1$  and  $r_2$ , we know that the quadratic factors as  $a(x - r_1)(x - r_2)$ . We know  $a = 396$  and  $p(x)$  has roots  $r_1 = \frac{45}{44}$  and  $r_2 = \frac{400}{9}$ . But then...

$$\begin{aligned} p(x) &= a(x - r_1)(x - r_2) \\ &= 396 \left( x - \frac{45}{44} \right) \left( x - \frac{400}{9} \right) \\ &= (44 \cdot 9) \left( x - \frac{45}{44} \right) \left( x - \frac{400}{9} \right) \\ &= 44 \left( x - \frac{45}{44} \right) \cdot 9 \left( x - \frac{400}{9} \right) \\ &= (44x - 45)(9x - 400) \end{aligned}$$

**Check-In 03/03.** (True/False) Because  $f(x) = x^2 - 6x - 27$  factors as  $(x+3)(x-9)$ , the discriminant of  $f(x)$  is a positive, perfect square. Furthermore,  $f(x)$  has two real roots.

**Solution.** The statement is *true*. The discriminant of a quadratic function  $ax^2 + bx + c$  is  $D = b^2 - 4ac$ . We know a polynomial factors ‘nicely’ if and only if  $D$  is a perfect square. Observe that  $f(x) = x^2 - 6x - 27 = (x+3)(x-9)$  factors ‘nicely.’ Therefore, the discriminant of  $f(x)$  must be a perfect square. In fact, we have...

$$D = b^2 - 4ac = (-6)^2 - 4(1)(-27) = 36 + 108 = 144 = 12^2$$

Clearly,  $D$  is a perfect square. [One can also see this via  $\sqrt{D} = \sqrt{144} = 12$ .] Furthermore, the polynomial  $ax^2 + bx + c$  has real roots if and only if  $D \geq 0$  (and only two distinct roots if  $D > 0$ ). Finally, the roots of  $ax^2 + bx + c$  are ‘nice’ if and only if  $D$  is a perfect square. Because we know that the discriminant of  $f(x)$  must be a perfect square, it must have ‘nice’ real roots. Because the factors of  $f(x)$  are distinct (so that  $D \neq 0$ ), we know that  $f(x)$  must have two distinct roots. Alternatively, we can see that if  $(x+3)(x-9) = 0$ , that either  $x+3 = 0$  (which implies that  $x = -3$ ) or  $x-9 = 0$  (which implies that  $x = 9$ ). Clearly,  $f(x)$  then has two real roots.

**Check-In 03/04.** (True/False) The domain of  $f(x) = \sqrt{x+5}$  is  $x > -5$ .

**Solution.** The statement is *false*. We know that the domain of  $\sqrt{\square}$  is all the  $x$ -values such that  $\square \geq 0$ . But then the domain of  $f(x)$  must be the  $x$ -values such that  $x+5 \geq 0$ . But then  $x \geq -5$ . The difference between this and the given solution is that  $x = -5$  is allowed. Observe that  $f(-5) = \sqrt{-5+5} = \sqrt{0} = 0$ , so that  $x = -5$  is in the domain of  $f(x)$ . Therefore, the domain of  $f(x)$  is  $[-5, \infty)$ , i.e. the  $x$ -values such that  $x \geq -5$ .

**Check-In 03/05.** (True/False) The domain of  $f(x) = (x-2)^2 + 3$  is all reals except  $x = 2$  and the range is  $[3, \infty)$ .

**Solution.** The statement is *false*. The function  $f(x)$  is a polynomial—a quadratic polynomial. The domain of any polynomial is all real numbers, i.e.  $(-\infty, \infty)$  or  $\mathbb{R}$ . The second statement is correct. Observe that  $f(x)$  is a quadratic function written in vertex form. We can see that the vertex is  $(2, 3)$ . Furthermore,  $a = 1 > 0$  so that  $f(x)$  opens upwards. But then  $f(x)$  has a minimum value—the  $y$ -coordinate of the vertex. We see that the minimum value is then 3. We know that  $f(x)$  takes on every  $y$ -value at or above its vertex. Therefore, the range of  $f(x)$  is  $[3, \infty)$ .

**Check-In 03/06.** (True/False) If  $f, g$  are functions  $(f \circ g)(x) = (g \circ f)(x)$ .

**Solution.** The statement is *false*. Function composition is *not* generally commutative—unlike multiplication. For instance, take  $f(x) = 1$  and  $g(x) = 2$ . Then...

$$(f \circ g)(x) = f(g(x)) = f(2) = 1$$

$$(g \circ f)(x) = g(f(x)) = g(1) = 2$$

Clearly,  $(f \circ g)(x) \neq (g \circ f)(x)$  for this choice of  $f(x)$  and  $g(x)$ .



**Check-In 03/17.** (True/False) If  $f(x) = 3x - 5$  and  $g(x) = 1 - x$ , then  $(f \circ g)(0) = f(0)g(0) = -5$ .

**Solution.** The statement is *false*. Recall that  $f \circ g$  is function composition—not multiplication. We have...

$$(f \circ g)(0) = f(g(0)) = f(1) = -2$$

where we have used the fact that  $g(0) = 1 - 0 = 1$  and  $f(1) = 3(1) - 5 = 3 - 5 = -2$ . On the other hand,  $(fg)(0) = f(0)g(0) = -5 \cdot 1 = -5$ —the given (incorrect) solution.

**Check-In 03/18.** (True/False) The graph of  $f(x + 2) - 4$  is the same as the graph of  $f(x)$  shifted to the left 2 and down by 4.

**Solution.** The statement is *true*. Recall that the graph of  $f(x \pm a)$  is the graph of  $f(x)$  shifted  $a$  units to the left (if it is  $+a$ ) or  $a$  units to the right (if it is  $-a$ ). We have  $f(x + 2)$ , so that we have shifted 2 units to the left. Recall also that the graph of  $f(x) \pm a$  is the graph of  $f(x)$  shifted  $a$  units downwards (if it is  $-a$ ) or  $a$  units upwards (if it is  $+a$ ). We have  $f(x + 2) - 4$ , so that we have shifted this new graph down by 4. Therefore, the graph of  $f(x + 2) - 4$  is the result of shifting the graph of  $f(x)$  two units to the left and four units downward.

**Check-In 03/19.** (True/False) The graph of  $f(-x)$  is a reflection across the  $x$ -axis.

**Solution.** The statement is *false*. Recall that the graph of  $f(-x)$  is the graph of  $f(x)$  reflected across the  $y$ -axis, whereas the graph of  $-f(x)$  is the graph of  $f(x)$  reflected across the  $x$ -axis. The given function has a graph that is the reflection of the graph of  $f(x)$  reflected across the  $y$ -axis. We can see this with an example: if  $f(1) = 3$ , then  $f(-1) = 3$  must be on the graph of  $f(-x)$ . But the points  $(1, 3)$  and  $(-1, 3)$  are reflections of each other across the  $y$ -axis.

**Check-In 03/20.** (True/False) A function  $f(x)$  has an inverse if and only if every horizontal line intersects the graph of  $f(x)$  at most once.

**Solution.** The statement is *true*. This is the Horizontal Line Test. If a horizontal line  $y = a$  intersects the graph of a function  $f(x)$  at most once, then there is at most one value  $x$  such that  $f(x) = a$ . But then  $f^{-1}(a) = x$ . Furthermore, if  $f^{-1}(y)$  is a function, then given an input  $y$  there is only one possible output—say  $x$ . But then  $f(x) = y$ . But then the line  $y = f(x)$  intersects the graph of  $f(x)$  only once (at the point  $(x, y)$ ).

**Check-In 03/24.** (True/False) If  $f(1) = 2$ ,  $f(2) = 3$ , and  $f(3) = 2$ , then it is not possible for  $f(x)$  to have an inverse.

**Solution.** The statement is *true*. Recall that  $f^{-1}(y)$  asks the question, “What value  $x$  do we plug into  $f(x)$  to obtain  $y$ ?” That is,  $f^{-1}(y) = x$  if and only if  $f(x) = y$ . But then  $f^{-1}(2)$  asks the question,

“What  $x$ -value do we plug into  $f(x)$  to obtain 2?” But  $f(1) = 2$  and  $f(3) = 2$ , and we cannot tell whether  $f^{-1}(2) = 1$  or  $f^{-1}(2) = 3$ , i.e.  $f^{-1}(2)$  is not well defined. We can also clearly see that the graph of  $f(x)$  must fail the horizontal line test. A function with repeated outputs—for example 2—cannot possibly have an inverse.

**Check-In 03/25.** (True/False) If  $f(x)$  is a function with an inverse, then  $f(f^{-1}(\sqrt[3]{\pi})) = \sqrt[3]{\pi}$ .

**Solution.** The statement is *true*. Recall that the inverse of a function  $f(x)$  is a function  $f^{-1}(x)$  such that  $(f \circ f^{-1})(x) = x$  and  $(f^{-1} \circ f)(x) = x$ , i.e.  $f(f^{-1}(x)) = x$  and  $f^{-1}(f(x)) = x$ . But then  $f(f^{-1}(\sqrt[3]{\pi})) = \sqrt[3]{\pi}$ . Alternatively, we know that  $f^{-1}(\sqrt[3]{\pi})$  represents the number, say  $a$ , that when plugged into  $f(x)$  gives us  $\sqrt[3]{\pi}$ , i.e.  $f(a) = \sqrt[3]{\pi}$ . But then  $f(f^{-1}(\sqrt[3]{\pi})) = f(a) = \sqrt[3]{\pi}$ .

**Check-In 03/26.** (True/False) If  $f(x)$  is a quadratic function with  $a = 1$  and roots  $-4$  and  $5$ , then  $f(x) = 1(x + 4)(x - 5)$ .

**Solution.** The statement is *true*. If  $ax^2 + bx + c$  has roots  $r_1$  and  $r_2$ , we know that the quadratic factors as  $a(x - r_1)(x - r_2)$ . We have  $a = 1$  and roots  $r_1 = -4$  and  $r_2 = 5$ . But then...

$$f(x) = a(x - r_1)(x - r_2) = 1(x - (-4))(x - 5) = (x + 4)(x - 5)$$

**Check-In 04/01.** (True/False) The exponential function  $f(x) = 3(2^{1-x})$  exponentially decreases.

**Solution.** The statement is *true*. If the exponential function  $y = Ab^x$  has  $A > 0$ , then  $y$  exponentially increases if  $b > 1$  and exponentially decreases if  $0 < b < 1$ . Observe that...

$$f(x) = 3(2^{1-x}) = 3(2^1 2^{-x}) = (3 \cdot 2)2^{-x} = 6(2^{-x}) = 6(2^{-1})^x = 6\left(\frac{1}{2}\right)^x$$

Therefore,  $f(x)$  is exponential with  $A = 6$  and  $b = \frac{1}{2}$ . Because  $0 < \frac{1}{2} < 1$ , we know that  $f(x)$  is exponentially decreasing.

**Check-In 04/02.** (True/False) The exponential function  $y = 15.3(1.13)^x$  can be thought of as having an initial value of 15.3 and a growth rate of 13%.

**Solution.** The statement is *true*. An exponential function of the form  $y = Ab^x$  has  $y$ -intercept  $A$ . If we write  $b = 1 \pm g$ , then  $g$  is the growth/decay rate of  $y$ . Observe that...

$$y = 15.3(1.13)^x = 15.3(1 + 0.13)^x$$

For this exponential function, we have  $A = 15.3$ ,  $b = 1.13$ , and  $g = 0.13$ . Therefore, the initial value is  $A = 15.3$  and the growth rate is 0.13, i.e. 13%.

**Check-In 04/03.** (*True/False*) The function which represents an initial value of \$50.55 that doubles in value every 7 years is  $f(x) = 50.55(2^{x/7})$ .

**Solution.** The statement is *true*. If a function has an initial value of  $A$  and doubles at an interval of  $d$ , then the function is given by  $y = A(2^{x/d})$ . If we need an initial value of 50.55, we need to choose  $A = 50.55$ . As we need the function to double every step size of 7, we need to choose  $d = 7$ . But then  $f(x) = A(2^{x/d}) = 50.55(2^{x/7})$ .

**Check-In 04/07.** (*True/False*) The continuous growth rate of  $y = e^{0.03x}$  is 0.03.

**Solution.** The statement is *true*. Given the function  $y = Ae^{kx}$ , we call the value  $k$  the continuous growth rate for  $y$ . We have here  $A = 1$  and  $k = 0.03$ .

**Check-In 04/08.** (*True/False*)  $\log_5 \left( \frac{1}{25} \right) = -2$

**Solution.** The statement is *true*. Recall that  $\log_b(y)$  stands for the power of  $b$  that yields the value  $y$ , i.e. if  $x = \log_b(y)$ , then  $b^x = y$ . Because  $5^{-2} = \frac{1}{5^2} = \frac{1}{25}$ , it must be that  $\log_5 \left( \frac{1}{25} \right) = -2$ .

**Check-In 04/09.** (*True/False*) For any base  $b > 0$ ,  $\log_b(1) = 0$  and  $\log_b(b^x) = x$ .

**Solution.** The statement is *true*. Recall that  $\log_b(y)$  stands for the power of  $b$  that yields the value  $y$ , i.e. if  $x = \log_b(y)$ , then  $b^x = y$ . For any nonzero  $b$ , we know that  $b^0 = 1$ . But this shows that  $\log_b(1) = 0$ . Furthermore, because  $b^x = b^x$ , it must be that  $\log_b(b^x) = x$ .

**Check-In 04/10.** (*True/False*) The value of  $\log_2(5)$  is the same as that of  $\frac{\ln 5}{\ln 2}$ .

**Solution.** The statement is *true*. Recall the change of base formula:  $\log_b(x) = \frac{\log_c(x)}{\log_c(b)}$ . Choosing base  $b = e$ , we have...

$$\log_2(5) = \frac{\log_e(5)}{\log_e(2)} = \frac{\ln(5)}{\ln(2)} \approx \frac{1.60944}{0.693147} = 2.32193$$

**Check-In 04/14.** (*True/False*) The amount in account after 5 years that initially contained \$120 and earns 4.1% annual interest, compounded continuously is given by  $120e^{0.041(5)}$ .

**Solution.** The statement is *true*. Recall that if an initial amount,  $P$ , (called the principal) is invested

at an annual interest rate of  $r$  (written as a decimal) that earns annual interest, compounded continuously, then the amount in the account after  $t$  years is given by  $y = Pe^{rt}$ . Here, we have an initial amount  $P = 120$  and an annual interest rate of  $r = 0.041$ . After  $t = 5$  years, the amount in the account is  $Pe^{rt} = 120e^{0.041(5)} \approx 147.30$ .

**Check-In 04/15.** (*True/False*) If \$5,280 is invested at 0.1% annual interest, compounded continuously, then it will take 20 years for the investment to be worth \$8,000.

**Solution.** The statement is *false*. Recall that if an initial amount,  $P$ , (called the principal) is invested at an annual interest rate of  $r$  (written as a decimal) that earns annual interest, compounded continuously, then the amount in the account after  $t$  years is given by  $y = Pe^{rt}$ . We have  $P = \$5280$  and  $r = 0.001$ . We want to know at what time  $t$  this amount will be \$8,000. But then...

$$\begin{aligned} 5280e^{0.001t} &= 8000 \\ e^{0.001t} &= 1.51515 \\ \ln(e^{0.001t}) &= \ln(1.51515) \\ 0.001t &= 0.415515 \\ t &\approx 415.52 \end{aligned}$$

Therefore, it will take approximately 415.52 years for the investment to be worth \$8,000.

**Check-In 04/16.** (*True/False*) The function  $y = 2^{1-x}$  is exponentially increasing.

**Solution.** The statement is *false*. An exponential function of the form  $y = Ab^x$ , where  $A > 0$ , is exponentially increasing if  $b > 1$  and exponentially decreasing if  $0 < b < 1$ . Observe that...

$$y = 2^{1-x} = 2^1 2^{-x} = 2 \cdot (2^{-1})^x = 2 \left(\frac{1}{2}\right)^x$$

This function is exponential with  $A = 2$  and  $b = \frac{1}{2}$ . Because  $0 < b < 1$ , the function is exponentially decreasing.