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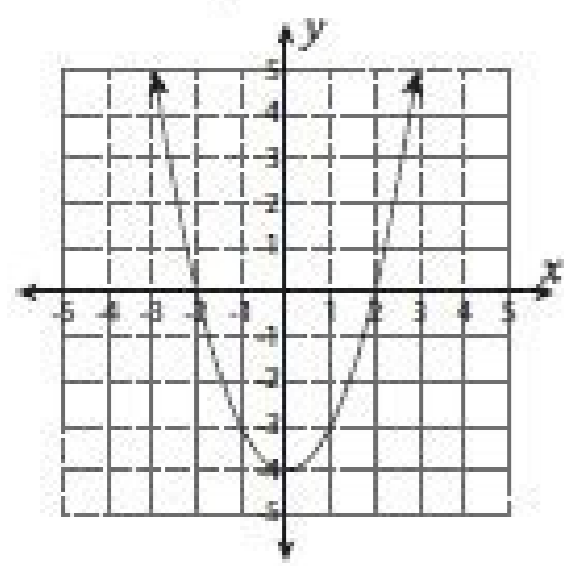
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Translation - Graph

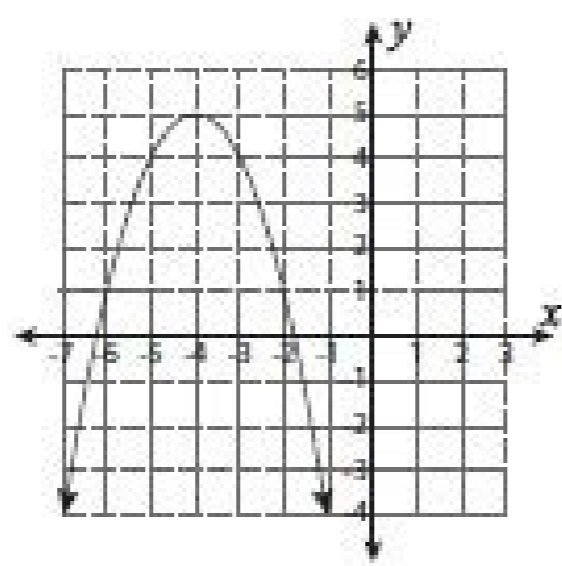
L1S1

Draw the translated graph.

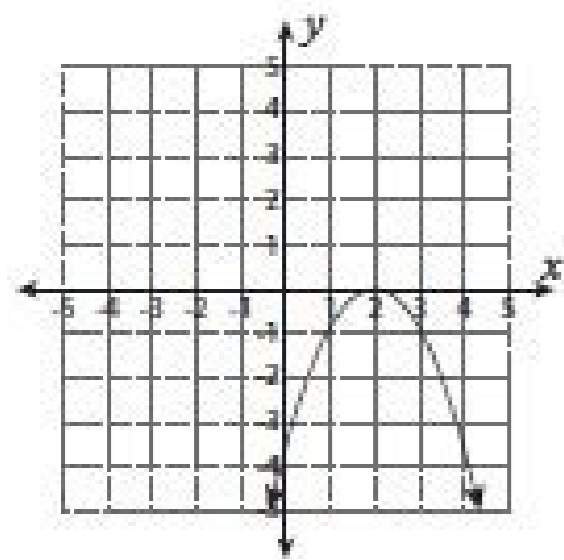
1) 3 units up



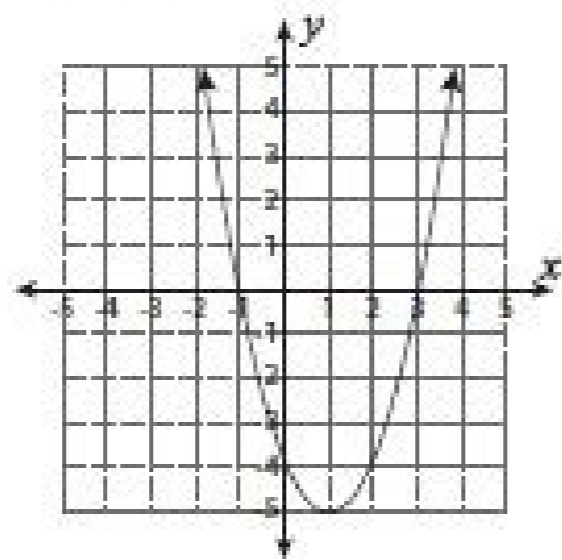
2) 2 units down



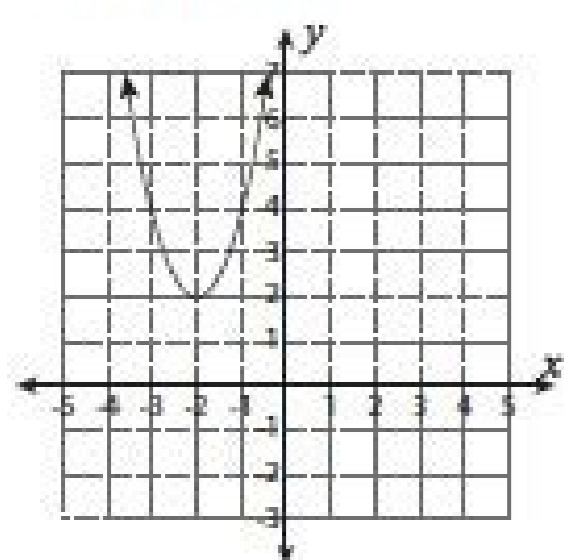
3) 5 units left



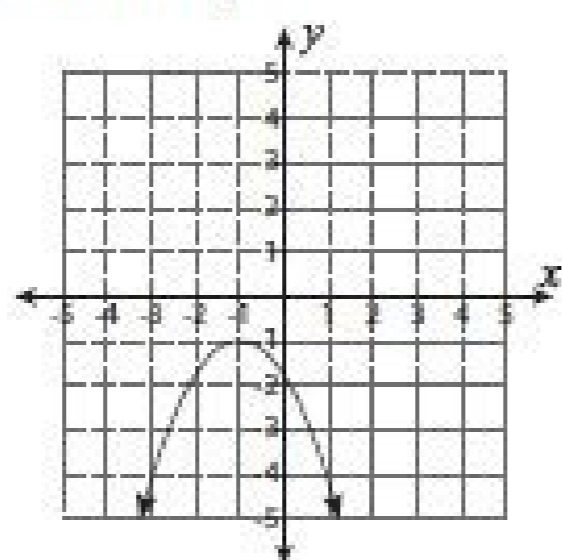
4) 1 unit right



5) 4 units down



6) 6 units up



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Inverses of Functions

Determine whether the functions are inverses.

1) $f(m) = \frac{2}{7}m - 3$
 $g(m) = 1m$

2) $f(b) = \frac{-2-5b}{2}$
 $g(b) = \frac{2b-2}{-5}$

3) $f(k) = 7k - 11$
 $g(k) = \frac{k+11}{7}$

4) $f(q) = (q + 6)^2$
 $g(q) = q^2 - 6$

5) $f(z) = -11(z - 3)^2$
 $g(z) = \left(\frac{z}{-11}\right)^2 + 3$

6) $f(y) = -7y$
 $g(y) = \frac{y}{-7}$

Find the inverse of each function.

7) $f(x) = \frac{5}{11}x + 2$

8) $f(n) = \frac{8+5n}{2}$

9) $f(d) = -5d + 11$

10) $f(s) = (s + 7)^4$

11) $f(w) = -7(w + 4)^2$

12) $f(r) = -4r$

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Two-Step Transformations (I)

Introduction: Transform each shape twice using the instructions in the order given. Draw and label each transformation.

1) Translate 2 units right.

2) Rotate 90 degrees counter-clockwise.

3) Translate 1 unit left.

4) Rotate 90 degrees clockwise.

5) Translate 2 units down.

6) Rotate 90 degrees counter-clockwise.

I. Model Problems

In this example we will evaluate a function for a given value of x.

Example 1: If f(x) = 5x + 3 and g(x) = 3x^2, find f(g(4)).

Substitute 4 for x for the function g(x). Simplify.

f(g(4))

f(3 * 4^2)

f(3 * 16)

f(48)

Substitute 48 for x for the function f(x). Simplify.

5(48) + 3

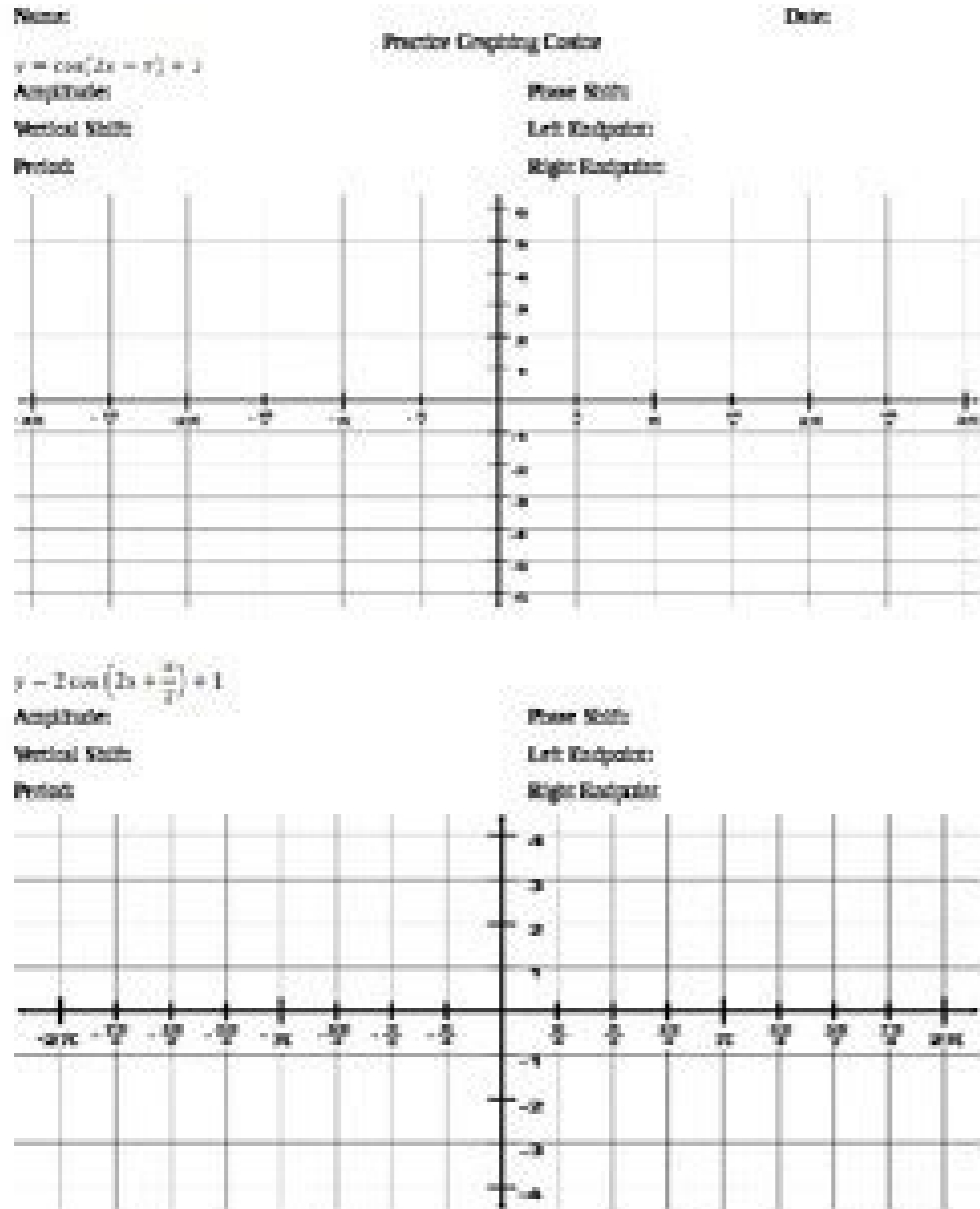
240 + 3

243

Answer: f(g(4)) = 243

A word on notation

f o g(4) is another way of expressing f(g(4))



For the following exercises, find functions f(x) and g(x) so the given function can be expressed as h(x)=f(g(x)). f(x)=x-1 and g(x)=x^2-1 f(x)=x-1 and g(x)=x^2-1 Are they the same function? What is the composition of two functions, f-g? The expression f(g(y)) f(g(y)) is meaningless. Figure 3 shows how we can mark the graphs with arrows to trace the path from the input value to the output value. We follow the usual convention with parentheses by starting with the innermost parentheses first, and then working to the outside. We evaluate the inside function first and then use the output of the inside function as the input to the outside function. f(2)=8. Solve m(A(d))=4. f(x)=4x+8,g(x)=7-x^2 f(x)=4x+8,g(x)=7-x^2 73. C(D(p))=6, g(f(0))=1, h(x)=4(x+2)^2 h(x)=4(x+2)^2 30. g(x)=1. A(m(t))=4. f(x)=|x|,g(x)=5x+1 f(x)=|x|,g(x)=5x+1 15. G(r)=(g-f)(2). Solve D(C(x))=6. It is irrelevant that the expressions happen to be equal for the single input value x=-1.2. Given f(x)=x^2+2x and g(x)=6-x^2, g(x)=6-x^2. find f+g,f-g,fg, f+g,f-g,fg, and f g. We read the input and output values, but this time, from the x- and y- axes of the graphs. 80. (g-f)(x)=F(x). 84. 38. Let us assume we know the domains of the functions f and g separately. Likewise, the domain of f f consists of all real numbers except 1. Given f(x)=1-x-4 and g(x)=1-6-x, g(x)=1-6-x, find f+g,f-g,fg, f+g,f-g,fg, and f g. 4. A store offers customers a 30% discount on the price x of selected items. f-g? The input value to the outer function will be the output of the inner function, which may be a numerical value, a variable name, or a more complicated expression. Trying to input a number of gallons does not make sense. We will also see that sometimes two functions can be composed only in one specific order. (f-g)(x)? Evaluate m(A(4)). f(g(x))=f(x)g(x). What is the domain of (f-g)(x)? Find those inputs x in the domain of g for which g(x) g(x) is in the domain of f. Find the area of the ripple at t=2. If the radius, in inches, grows as a function of time in minutes according to r(t)=25t+2, r(t)=25t+2, find the area of the ripple as a function of time. If the radius of the circle of burning grass is increasing with time according to the formula r(t)=2t+1, r(t)=2t+1, express the area burned as a function of time, t (minutes). Find and simplify the functions (fg)(x) (fg)(x) and (f-g)(x) (f-g)(x). Performing algebraic operations on functions combines them into a new function, but we can also create functions by composing functions. For f(x)=1-x and g(x)=x-1, write the domain of (fg)(x) (fg)(x) in interval notation. Suppose we need to add two columns of numbers that represent a husband and wife's separate annual incomes over a period of years, with the result being their total household income. In this way, we can think of adding, subtracting, multiplying, and dividing functions. Since square roots are positive, 3-x >= 0, 3-x >= 0, or, 3-x >= 0, 3-x >= 0, which gives a domain of (-infinity, 3]. h(x)=1/3(x^2-4)-3 h(x)=1/3(x^2-4)-3 33. f(x)=x+2,g(x)=x^2+3 f(x)=x+2,g(x)=x^2+3 14. Given a function composition f(g(x)), f(g(x)), determine its domain. Find the domain of g. x x f(x) f(x) g(x) g(x) 1 6 3 2 8 5 3 3 2 4 1 7 To evaluate f(g(3)), f(g(3)), we start from the inside with the input value 3. While we can compose the functions for each individual input value, it is sometimes helpful to find a single formula that will calculate the result of a composition f(g(x)). Then, we could evaluate the cost function at that temperature. When the food is removed from the refrigerator, the temperature is given by T(t)=5t+1.5, T(t)=5t+1.5, where t is the time in hours. Find the composite function N(T(t)). p. f(g(1))=6. Less formally, the composition has to make sense in terms of inputs and outputs. The function C(T) C(T) gives the cost C of heating a house for a given average daily temperature in T degrees Celsius. 56. Evaluate composite functions. The domain of a composite function f(g(x)) f(g(x)) is the set of those inputs x in the domain of g for which g(x) g(x) is in the domain of f. 31. Given f(t)=t^2-t f(t)=t^2-t and h(x)=3x+2, h(x)=3x+2, evaluate f(h(1)). h(x)=(x+2)^2 h(x)=(x+2)^2 27. It is important to know when we can apply a composite function and when we cannot, that is, to know the domain of a function such as f-g. Find the exact time when the radius reaches 10 inches. Simplify your answers. A(m(4)). In general, f-g f-g and g-f-g are different functions. Determine the domain of the function in interval notation. Composition is a binary operation that takes two functions and forms a new function, much as addition or multiplication takes two numbers and gives a new number. C(D(6)). The open circle symbol o is called the composition operator. To determine the cost of production when the price is \$6, you would do which of the following? Which of the following would you do in order to determine when the patient will be at a pain level of 4? 52. Suppose we want to calculate how much it costs to heat a house on a particular day of the year. For the following exercises, let F(x)=(x+1)^5, F(x)=(x+1)^5, f(x)=x^5, f(x)=x^5, and g(x)=x+1. The process of combining functions so that the output of one function becomes the input of another is known as a composition of functions. C(T(5)). When we are given individual functions as graphs, the procedure for evaluating composite functions is similar to the process we use for evaluating tables. Air is pumped into the balloon, so the volume after t seconds is given by V(t)=10+20t. How does one find the domain of the quotient of two functions. f g? In each case, we evaluate the inner function using the starting input and then use the inner function's output as the input for the outer function. x x f(x) f(x) g(x) g(x) 079 165 256 382 441 508 627 713 894 930 58. Find (f-g)(2) (f-g)(2) and (g-f)(2). Given f(x)=-3x^2+x f(x)=-3x^2+x and g(x)=5, g(x)=5, find f+g,f-g,fg, f+g,f-g,fg, and f g. 18. For any input x and functions f and g, g, this action defines a composite function, which we write as f-g such that (f-g)(x)=f(g(x)) (f-g)(x)=f(g(x)) The domain of the composite function f-g f-g is all x such that x is in the domain of g and g(x) g(x) is in the domain of f. That is, exclude those inputs x in the domain of g for which g(x) g(x) is not in the domain of f. m(t). It is also important to understand the order of operations in evaluating a composite function. 11. If yes, give an example. Note that the domain of f f composed with g g is the set of all x such that x is in the domain of g and g(x) g(x) is in the domain of f. 3. Locate the given input to the inner function on the x- axis of its graph. (f-g)(6);(g-f)(6) (f-g)(6);(g-f)(6) 88. However, we also see that g(x) g(x) must be a member of the domain of f, otherwise the second function evaluation in f(g(x)) f(g(x)) cannot be completed, and the expression is still undefined. 36. x=-1.2. Thus, we can evaluate the cost function at the temperature T(d). True or False: (g-f)(x)=F(x). This example shows that knowledge of the range of functions (specifically the inner function) can also be helpful in finding the domain of a composite function. We represent this combination by the following notation: (f-g)(x)=f(g(x)) (f-g)(x)=f(g(x)) We read the left-hand side as "f of g of x" and the right-hand side as "f of g of x". The two sides of the equation have the same mathematical meaning and are equal. 12. This means that x^2 3 or x^2 3 or x^2 3 or x^2 3. We can write this in interval notation as (-infinity, 2.3) union (2.3, infinity) (-infinity, 2.3) union (2.3, infinity) Find the domain of (f-g)(x) where f(x)=x^2 and g(x)=3-x (f-g)(x) where f(x)=x^2 and g(x)=3-x Because we cannot take the square root of a negative number, the domain of g is (-infinity, 3]. Then, using the table for g, g, we can evaluate g(f(3))=g(3)=2 Table 2 shows the composite functions f-g f-g and g-f-g as tables. We can then use that result as the input to the function f, so g(3) g(3) is replaced by 2 and we get f(2). (f-g)(x). Now we check the domain of the composite function (f-g)(x)=3-x+2 For (f-g)(x)=3-x+2, 3-x+2 >= 0, (f-g)(x)=3-x+2, 3-x+2 >= 0, since the radicand of a square root must be positive. Find the domain of f. Determine whether the composition of the functions is commutative. This is the output of the composite function. As one possibility, we might notice that the expression 5-x^2 5-x^2 is the inside of the square root. To do this, we look for a function inside a function in the formula for (x, g(x) g(x) x^2 -1. If the order is reversed when composing two functions, can the result ever be the same as the answer in the original order of the composition? Given f(x)=x f(x)=x and g(x)=|x-3|, g(x)=|x-3|, find g f. Given functions q(x)=1-x q(x)=1-x and h(x)=x^2-9, h(x)=x^2-9, state the domain of each of the following functions using interval notation. The gravitational force on a planet a distance r from the sun is given by the function G(r). 83. Determine the domain for each function in interval notation. f(x)=x^2+1, f(x)=x^2+1, g(x)=1-x, g(x)=1-x, and h(x)=x+3 h(x)=x+3 20. g(f(x))=3-(2x+1) =3-2x-1 =-2x+2 g(f(x))=3-(2x+1) =3-2x-1 =-2x+2 We find that g(f(x))=f(g(x)), g(f(x))=f(g(x)), so the operation of function composition is not commutative. 1.4 Section Exercises 1. Evaluate the inside function using the input value or variable provided. h(x)=(8+x^3 8-x^3) 4 h(x)=(8+x^3 8-x^3) 4 35. 4 3x-2 =1 4=3x-2 6=3x x^2 4 3x-2 =1 4=3x-2 6=3x x^2 So the domain of f-g f-g is the set of all real numbers except 2 3 3 and 2. 91. f(h(1))=f(5) f(h(1))=5 2 -5 f(h(1))=20 f(h(1))=f(5) f(h(1))=5 2 -5 f(h(1))=20 It makes no difference what the input variables 1 and x were called in this problem because we evaluated for specific numerical values. 60. Given f(x)=2x^2+1 f(x)=2x^2+1 and g(x)=3x-5, g(x)=3x-5, find the following: f(g(2)) f(g(2)) f(g(x)) f(g(x)) g(f(x)) g(f(x)) (g-f)(x) (g-f)(x) (f+g)(x) (f+g)(x) For the following exercises, use each pair of functions to find f(g(x)) f(g(x)) and g(f(x)). Find the domain of (f-g)(x) where f(x)=5x-1 and g(x)=4 3x-2 (f-g)(x) where f(x)=5x-1 and g(x)=4 3x-2 The domain of (g(x) g(x)) consists of all real numbers except x=2 3, x=2 3, since that input value would cause us to divide by 0. The acceleration of a planet subjected to any force F is given by the function a(F). f(x) g(x) =f(g(x)). Begin by writing the general form, and then substitute the given functions. Because the input to the s-function is time, t=3=3 represents 3 minutes, and s(3) s(3) is the number of sit-ups completed in 3 minutes. There may be more than one way to decompose a composite function, so we may choose the decomposition that appears to be most expedient. h(x)=(5x-1) 3 h(x)=(5x-1) 3 37. Find the time (round to two decimal places) when the bacteria count reaches 6752. f(x)=x^2+1,g(x)=x+2 f(x)=x^2+1,g(x)=x+2 13. The function y=f(x) y=f(x) is a function whose output is the number of miles driven corresponding to the number of hours driven. Are there any situations where f(g(y)) f(g(y)) and g(f(x)) g(f(x)) would both be meaningful or useful expressions? h(x)=|x^2+7| h(x)=|x^2+7| 39. In real-world problems, functions whose inputs and outputs have the same units also may give compositions that are meaningful in either order. Compare the two answers. a(F). (g-f)(a);(f-g)(a) (g-f)(a);(f-g)(a) 89. In other words, in many cases f(g(x)) =g(f(x)) f(g(x)) =g(f(x)) for all x. g(f(x)) For two functions f(x) f(x) and g(x) g(x) with real number outputs, we define new functions f+g,f-g,fg, f+g,f-g,fg, and f g by the relations (f+g)(x)=f(x)+g(x) (f-g)(x)=f(x)-g(x) (fg)(x)=f(x)g(x) (fg)(x)=f(x)g(x) (fg)(x)=f(x)g(x) (fg)(x)=f(x)g(x) Find and simplify the functions (g-f)(x) (g-f)(x) and (g f)(x), (g f)(x), given f(x)=x-1 f(x)=x-1 and g(x)=x^2-1. Using the functions provided, find f(g(x)) f(g(x)) and g(f(x)) f(g(x)) f(g(x)) f(g(h(4))) f(g(h(4))) 57. 59. Notice how we have just defined two relationships: The cost depends on the temperature, and the temperature depends on the day. 86. Write f(x)=5-x^2 f(x)=5-x^2 as the composition of two functions. Using descriptive variables, we can notate these two functions. 65. Given a formula for a composite function, evaluate the function. h(1)=3(1)+2 h(1)=5 Then f(h(1))=f(5), f(h(1))=f(5), so we evaluate f(h(1)) at an input of 5. Evaluate A(m(4)). For example, we could evaluate T(5) T(5) to determine the average daily temperature on the 5th day of the year. f(1))=(f(3) f(1))=f(3) We can then evaluate the composite function by looking to the graph of f(x), f(x), finding the input of 3 on the x- axis and reading the output value of the graph at this input. 8. The function T(d) T(d) gives the average daily temperature on day d of the year. f(x). D(C(x))=6. Using Table 1, evaluate f(g(3)) f(g(3)) and g(f(3)). Is (f-f)(x) (f-f)(x) for any function f the same result as the answer to part (a) for any function? (Hint: Use function composition to find your answer.) 93. Given f(x)=2x^2+4x f(x)=2x^2+4x and g(x)=1 2x, g(x)=1 2x, find f+g,f-g,fg, f+g,f-g,fg, and f g. t=2. The production cost C(x) C(x) is the cost of producing x items. 29. 2. Use the function you found in the previous exercise to find the total area burned after 5 minutes. g(x)=x-2. The radius r, in inches, of a spherical balloon is related to the volume, V, by r(V)=3V 4n 3. f(x)=5x+7,g(x)=4-2x^2 f(x)=5x+7,g(x)=4-2x^2 74. Given the functions f(x)=1-x and g(x)=1+x^2, f(x)=1-x and g(x)=1+x^2, find the following: (g-f)(x) (g-f)(x) (g-f)(2) (g-f)(2) 23. Which of these expressions is meaningful: f(g(y)) f(g(y)) or g(f(x)) g(f(x)) f. A forest fire leaves behind an area of grass burned in an expanding circular pattern. The expression f(x) f(x) takes hours as input and a number of miles driven as the output. Using Figure 1, evaluate g(f(2)). h(x)=1 2x-3 3 h(x)=1 2x-3 32. Function composition is only one way to combine existing functions. 51. The number of bacteria in a refrigerated food product is given by N(T)=23 T^2 -56T+1, N(T)=23 T^2 -56T+1, 3

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