Symmetries and operations on functions

Lesson #5

MAT 1375 Precalculus

New York City College of Technology CUNY

Even functions

A function is *even*, if

$$f(-x) = f(x) \quad \text{for all } x$$

Example: $f(x) = x^2$

Find $f(2) =$ $f(-2) =$

$f(3) =$ $f(-3) =$

Even functions

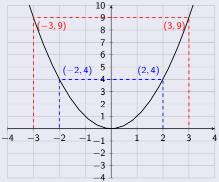
A function is *even*, if

$$f(-x) = f(x) \quad \text{for all } x$$

Example: $f(x) = x^2$

Find $f(2) = 4$ $\quad f(-2) = 4$

$f(3) = 9$ $\quad f(-3) = 9$



Even functions have graphs that are symmetric with respect to the y-axis.

Even and odd functions

Even functions

A function is *even*, if

$$f(-x) = f(x) \quad \text{for all } x$$

Example: $f(x) = x^2$

Find $f(2) = 4$ $\quad f(-2) = 4$

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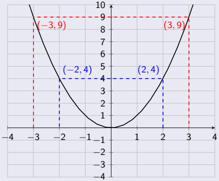

Even functions have graphs that are symmetric with respect to the y-axis.

Odd functions

A function is *odd*, if

$$f(-x) = -f(x) \quad \text{for all } x$$

Example: $f(x) = x^3$

Find $f(2) =$ $\quad f(-2) =$

Even and odd functions

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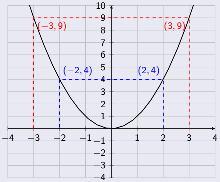


Even functions have graphs that are symmetric with respect to the y-axis.

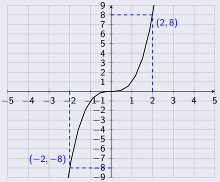
Odd functions

A function is *odd*, if

$$f(-x) = -f(x) \quad \text{for all } x$$

Example: $f(x) = x^3$

Find $f(2) = 8$ $\quad f(-2) = -8$



Odd functions have graphs that are symmetric with respect to the origin.

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Find $f(2) = 4$ $f(-2) = 4$

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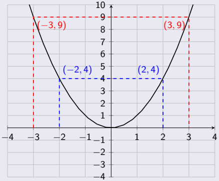

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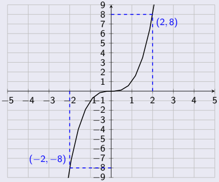


Odd functions have graphs that are symmetric with respect to the origin.

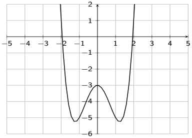
Note: If 0 is in the domain, then $f(0) = f(-0) = -f(0)$, so that:

$$f(0) = 0$$

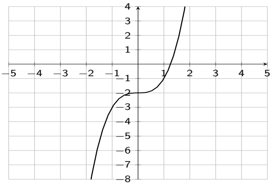
Even and odd functions - exercises

Determine if the function is even, odd, or neither.

1. $f(x) = x^4 - 3x^2 - 3$



2.

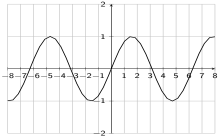


3. $f(x) = \frac{1}{x^3} - \frac{4}{x}$

4. $f(x) = x^3 + x^6$

5. $f(x) = \frac{x^2+2}{x^4-3}$

6.



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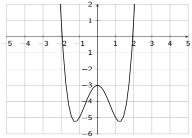

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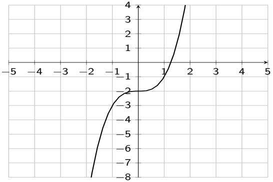
2. 

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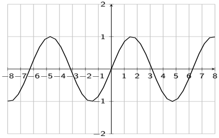
6. 

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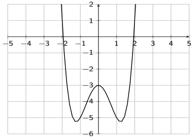

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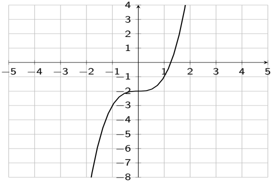
2. 

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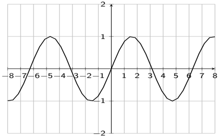
6. 

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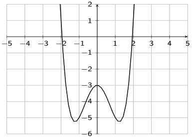

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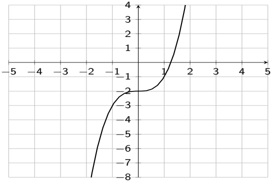
2. 

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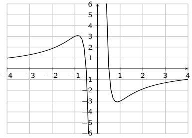

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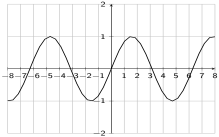
6. 

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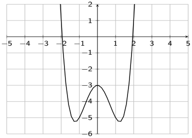

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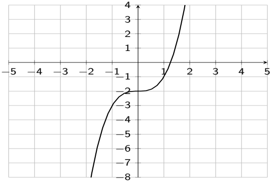
2. 

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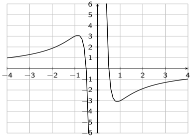

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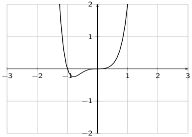

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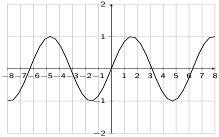
6. 

Determine if the function is even, odd, or neither.

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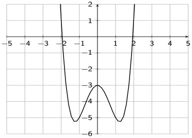

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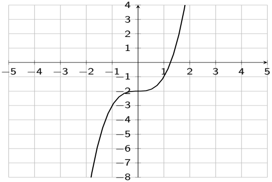
2. 

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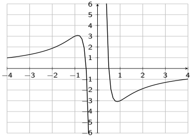

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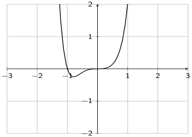

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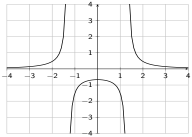

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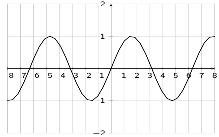
6. 

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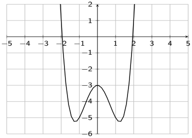

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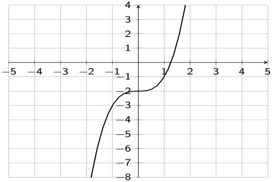
2. 

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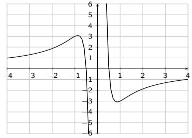

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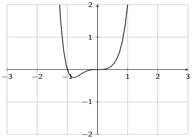

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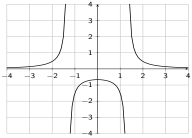

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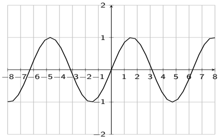
6. 

Odd

Addition, subtraction, multiplication, division

1. Let $f(x) = x^2 + 7x + 12$ and $g(x) = 2x - 6$.
   - Find the sum $(f + g)(x) = f(x) + g(x)$
   - Find the difference $(f - g)(x) = f(x) - g(x)$
   - Find the product $(f \cdot g)(x) = f(x) \cdot g(x)$
   - Find the quotient $\frac{f}{g}(x) = \frac{f(x)}{g(x)}$
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Addition, subtraction, multiplication, division

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   - Find the sum $(f + g)(x) = f(x) + g(x)$
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     $= 2x^3 - 6x^2 + 14x^2 - 42x + 24x - 72$
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   Domains:
   $D_f =$
   $D_g =$

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Domains:
$D_f = \mathbb{R}$
$D_g = \mathbb{R}$

Domains:
$D_{f+g} =$

$D_{f-g} =$

$D_{f \cdot g} =$

$D_{\frac{f}{g}} =$

$D_{\frac{g}{f}} =$

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   - Find the quotient $\frac{g}{f}(x) = \frac{g(x)}{f(x)} = \frac{2x-6}{x^2+7x+12}$

   Domains:
   $D_f = \mathbb{R}$
   $D_g = \mathbb{R}$

Domains:
$D_{f+g} = \mathbb{R}$

$D_{f-g} = \mathbb{R}$

$D_{f \cdot g} = \mathbb{R}$

$2x - 6 = 0 \Rightarrow 2x = 6 \Rightarrow x = 3$
$D_{\frac{f}{g}} = \mathbb{R} - \{3\}$

$D_{\frac{g}{f}} =$

1. Let $f(x) = x^2 + 7x + 12$ and $g(x) = 2x - 6$.
   - Find the sum $(f+g)(x) = f(x) + g(x)$
     $= (x^2 + 7x + 12) + (2x - 6) = x^2 + 9x + 6$
   - Find the difference $(f-g)(x) = f(x) - g(x)$
     $= (x^2 + 7x + 12) - (2x - 6) = x^2 + 5x + 18$
   - Find the product $(f \cdot g)(x) = f(x) \cdot g(x)$
     $= (x^2 + 7x + 12) \cdot (2x - 6)$
     $= 2x^3 - 6x^2 + 14x^2 - 42x + 24x - 72$
     $= 2x^3 + 8x^2 - 18x - 72$
   - Find the quotient $\frac{f}{g}(x) = \frac{f(x)}{g(x)} = \frac{x^2+7x+12}{2x-6}$
   - Find the quotient $\frac{g}{f}(x) = \frac{g(x)}{f(x)} = \frac{2x-6}{x^2+7x+12}$

   Domains:
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$2x - 6 = 0 \Rightarrow 2x = 6 \Rightarrow x = 3$
$D_{\frac{f}{g}} = \mathbb{R} - \{3\}$

$x^2 + 7x + 12 = 0$
$\Rightarrow (x+3)(x+4) = 0$
$\Rightarrow x = -3$ or $x = -4$
$D_{\frac{g}{f}} = \mathbb{R} - \{-3, -4\}$

Addition, subtraction, multiplication, division - exercise

2. Let $f(x) = \frac{1}{x-5}$ and $g(x) = \sqrt{x-2}$.
   - Find the sum $(f+g)(x) = f(x) + g(x)$
   - Find the difference $(f-g)(x) = f(x) - g(x)$
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Domains:

$D_f = \mathbb{R} - \{5\}$
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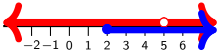

Addition, subtraction, multiplication, division - exercise

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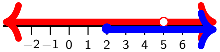

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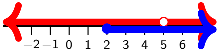

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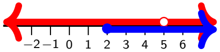

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We need $x \neq 5$, $x - 2 \geq 0$,
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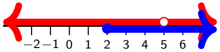

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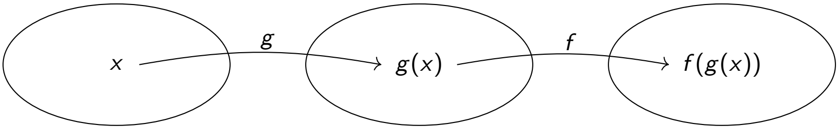
Composition

Use the output of the function g as an input for the function f:



Definition

The *composition* $f \circ g$ is the function $(f \circ g)(x) = f(g(x))$.
The domain of $f \circ g$ are all x for which $g(x)$ is defined and then $f(g(x))$ is also defined.

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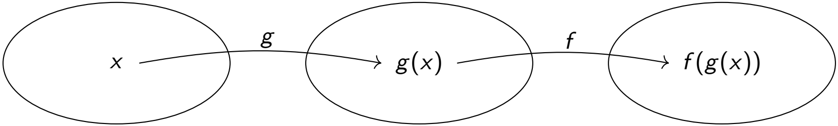
Use the output of the function g as an input for the function f:



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1. $f(x) = 2x + 1$
   $g(x) = x^2 - 5$
   Evaluate:
   $(f \circ g)(4) = f(g(4)) =$

   $(f \circ g)(3) = f(g(3)) =$

2. $f(x) = \frac{x+1}{x+2}$
   $g(x) = x + 3$
   Evaluate:
   $(f \circ g)(5) = f(g(5)) =$

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3. $f(x) = x^2 - 5x + 8$
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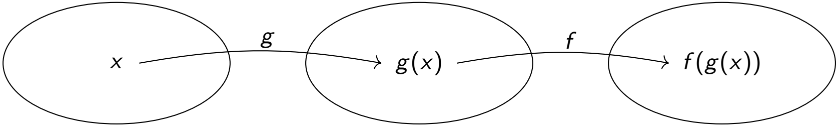

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1. $f(x) = 2x + 1$
   $g(x) = x^2 - 5$
   Evaluate:
   $(f \circ g)(4) = f(g(4)) = f(4^2 - 5)$
   $= f(11) = 2 \cdot 11 + 1 = 23$

   $(f \circ g)(3) = f(g(3)) =$

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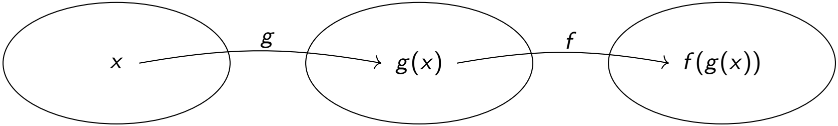

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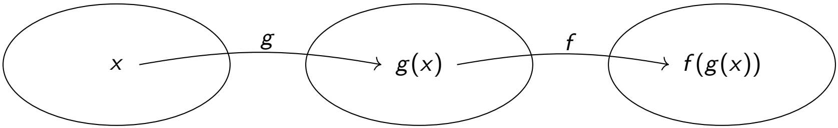

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   $= f(4) = 2 \cdot 4 + 1 = 9$

2. $f(x) = \frac{x+1}{x+2}$
   $g(x) = x + 3$
   Evaluate:
   $(f \circ g)(5) = f(g(5)) = f(5 + 3)$
   $= f(8) = \frac{8+1}{8+2} = \frac{9}{10}$

   $(g \circ f)(5) = g(f(5)) =$

3. $f(x) = x^2 - 5x + 8$
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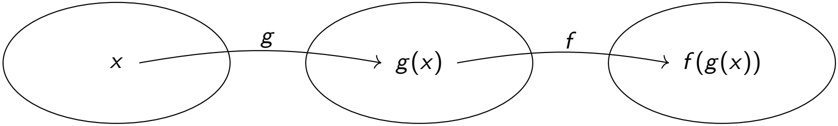

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   Evaluate:
   $(f \circ g)(4) = f(g(4)) = f(4^2 - 5)$
   $= f(11) = 2 \cdot 11 + 1 = 23$

   $(f \circ g)(3) = f(g(3)) = f(3^2 - 5)$
   $= f(4) = 2 \cdot 4 + 1 = 9$

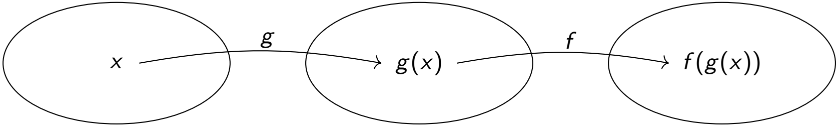
2. $f(x) = \frac{x+1}{x+2}$
   $g(x) = x + 3$
   Evaluate:
   $(f \circ g)(5) = f(g(5)) = f(5 + 3)$
   $= f(8) = \frac{8+1}{8+2} = \frac{9}{10}$

   $(g \circ f)(5) = g(f(5)) = g(\frac{5+1}{5+2})$
   $= g(\frac{6}{7}) = \frac{6}{7} + 3 = \frac{27}{7}$

3. $f(x) = x^2 - 5x + 8$
   $g(x) = x + 3$
   Evaluate:
   $(f \circ g)(x) = f(g(x)) =$

Composition

Use the output of the function g as an input for the function f:



Definition

The *composition* $f \circ g$ is the function $(f \circ g)(x) = f(g(x))$.
The domain of $f \circ g$ are all x for which $g(x)$ is defined and then $f(g(x))$ is also defined.

1. $f(x) = 2x + 1$
   $g(x) = x^2 - 5$
   Evaluate:
   $(f \circ g)(4) = f(g(4)) = f(4^2 - 5)$
   $= f(11) = 2 \cdot 11 + 1 = 23$

   $(f \circ g)(3) = f(g(3)) = f(3^2 - 5)$
   $= f(4) = 2 \cdot 4 + 1 = 9$

2. $f(x) = \frac{x+1}{x+2}$
   $g(x) = x + 3$
   Evaluate:
   $(f \circ g)(5) = f(g(5)) = f(5 + 3)$
   $= f(8) = \frac{8+1}{8+2} = \frac{9}{10}$

   $(g \circ f)(5) = g(f(5)) = g(\frac{5+1}{5+2})$
   $= g(\frac{6}{7}) = \frac{6}{7} + 3 = \frac{27}{7}$

3. $f(x) = x^2 - 5x + 8$
   $g(x) = x + 3$
   Evaluate:
   $(f \circ g)(x) = f(g(x)) =$
   $= f(x + 3)$
   $= (x + 3)^2 - 5(x + 3) + 8$
   $= x^2 + 6x + 9 - 5x - 15 + 8$
   $= x^2 + x + 2$

Find the compositions and state their domains.

4. $f(x) = x^2 + 3x$
   $g(x) = x - 7$
   $(f \circ g)(x) =$

5. $f(x) = \frac{x+2}{x-5}$
   $g(x) = x^2 + 4$
   $(f \circ g)(x) =$

6. $f(x) = x^2 + 4x + 6$
   $g(x) = 2x + 3$
   $(f \circ g)(x) =$

7. $f(x) = x^2 + 4x + 6$
   $g(x) = 2x + 3$
   $(g \circ f)(x) =$

Find the compositions and state their domains.

4. $f(x) = x^2 + 3x$
   $g(x) = x - 7$
   $(f \circ g)(x) = f(g(x))$
   $= f(x - 7)$
   $= (x - 7)^2 + 3 \cdot (x - 7)$
   $= x^2 - 14x + 49 + 3x - 21$
   $= x^2 - 11x + 28$
   Domain: $D = \mathbb{R}$

5. $f(x) = \frac{x+2}{x-5}$
   $g(x) = x^2 + 4$
   $(f \circ g)(x) =$

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Composition - exercises

Find the compositions and state their domains.

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   Domain: $D = \mathbb{R}$

5. $f(x) = \frac{x+2}{x-5}$
   $g(x) = x^2 + 4$
   $(f \circ g)(x) = f(g(x))$
   $= f(x^2 + 4)$
   $= \frac{x^2+4+2}{x^2+4-5} = \frac{x^2+6}{x^2-1}$
   Domain:
   Where is the denominator zero?
   $x^2 - 1 = 0$
   $(x + 1)(x - 1) = 0 \Rightarrow x = \pm 1$
   $\Rightarrow D = \mathbb{R} - \{-1, +1\}$

6. $f(x) = x^2 + 4x + 6$
   $g(x) = 2x + 3$
   $(f \circ g)(x) =$

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Composition - exercises

Find the compositions and state their domains.

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   Domain:
   Where is the denominator zero?
   $x^2 - 1 = 0$
   $(x+1)(x-1) = 0 \Rightarrow x = \pm 1$
   $\Rightarrow D = \mathbb{R} - \{-1, +1\}$

6. $f(x) = x^2 + 4x + 6$
   $g(x) = 2x + 3$
   $(f \circ g)(x) = f(g(x))$
   $= f(2x+3)$
   $= (2x+3)^2 + 4 \cdot (2x+3) + 6$
   $= 4x^2 + 12x + 9 + 8x + 12 + 6$
   $= 4x^2 + 20x + 27$
   Domain: $D = \mathbb{R}$

7. $f(x) = x^2 + 4x + 6$
   $g(x) = 2x + 3$
   $(g \circ f)(x) =$

Composition - exercises

Find the compositions and state their domains.

4. $f(x) = x^2 + 3x$
   $g(x) = x - 7$
   $(f \circ g)(x) = f(g(x))$
   $= f(x-7)$
   $= (x-7)^2 + 3 \cdot (x-7)$
   $= x^2 - 14x + 49 + 3x - 21$
   $= x^2 - 11x + 28$
   Domain: $D = \mathbb{R}$

5. $f(x) = \frac{x+2}{x-5}$
   $g(x) = x^2 + 4$
   $(f \circ g)(x) = f(g(x))$
   $= f(x^2 + 4)$
   $= \frac{x^2+4+2}{x^2+4-5} = \frac{x^2+6}{x^2-1}$
   Domain:
   Where is the denominator zero?
   $x^2 - 1 = 0$
   $(x+1)(x-1) = 0 \Rightarrow x = \pm 1$
   $\Rightarrow D = \mathbb{R} - \{-1, +1\}$

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   $g(x) = 2x + 3$
   $(f \circ g)(x) = f(g(x))$
   $= f(2x+3)$
   $= (2x+3)^2 + 4 \cdot (2x+3) + 6$
   $= 4x^2 + 12x + 9 + 8x + 12 + 6$
   $= 4x^2 + 20x + 27$
   Domain: $D = \mathbb{R}$

7. $f(x) = x^2 + 4x + 6$
   $g(x) = 2x + 3$
   $(g \circ f)(x) = g(f(x))$
   $= g(x^2 + 4x + 6)$
   $= 2 \cdot (x^2 + 4x + 6) + 3$
   $= 2x^2 + 8x + 12 + 3$
   $= 2x^2 + 8x + 15$
   Domain: $D = \mathbb{R}$

Find the compositions and state their domains.

8. $f(x) = \sqrt{3-2x}$
   $g(x) = 5 - 4x$
   $(f \circ g)(x) =$

10. $f(x) = \frac{1}{x^2-x-12}$
    $g(x) = 3x - 5$
    $(g \circ f)(x) =$

9. $f(x) = \sqrt{3-2x}$
   $g(x) = 5 - 4x$
   $(g \circ f)(x) =$

11. $f(x) = \frac{1}{x^2-x-12}$
    $g(x) = 3x - 5$
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Find the compositions and state their domains.

8. $f(x) = \sqrt{3-2x}$

   $g(x) = 5 - 4x$

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

   $= f(5-4x)$

   $= \sqrt{3 - 2 \cdot (5-4x)}$

   $= \sqrt{3 - 10 + 8x}$

   $= \sqrt{8x - 7}$

   Domain:

   $8x - 7 \geq 0 \quad \Rightarrow 8x \geq 7 \quad \Rightarrow x \geq \frac{7}{8}$

   $D = [\frac{7}{8}, \infty)$

9. $f(x) = \sqrt{3-2x}$

   $g(x) = 5 - 4x$

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

10. $f(x) = \frac{1}{x^2 - x - 12}$

    $g(x) = 3x - 5$

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

11. $f(x) = \frac{1}{x^2 - x - 12}$

    $g(x) = 3x - 5$

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

Find the compositions and state their domains.

8. $f(x) = \sqrt{3-2x}$
   $g(x) = 5 - 4x$
   $(f \circ g)(x) = f(g(x))$
   $= f(5-4x)$
   $= \sqrt{3 - 2 \cdot (5-4x)}$
   $= \sqrt{3 - 10 + 8x}$
   $= \sqrt{8x-7}$
   Domain:
   $8x - 7 \geq 0 \quad \Rightarrow 8x \geq 7 \quad \Rightarrow x \geq \frac{7}{8}$
   $D = [\frac{7}{8}, \infty)$
9. $f(x) = \sqrt{3-2x}$
   $g(x) = 5 - 4x$
   $(g \circ f)(x) = g(f(x))$
   $= g(\sqrt{3-2x})$
   $= 5 - 4 \cdot \sqrt{3-2x}$
   Domain:
   $3 - 2x \geq 0 \quad \Rightarrow -2x \geq -3 \quad \Rightarrow x \leq \frac{3}{2}$
   $D = (-\infty, \frac{3}{2}]$
10. $f(x) = \frac{1}{x^2-x-12}$
    $g(x) = 3x - 5$
    $(g \circ f)(x) =$
11. $f(x) = \frac{1}{x^2-x-12}$
    $g(x) = 3x - 5$
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Find the compositions and state their domains.

8. $f(x) = \sqrt{3-2x}$
   $g(x) = 5-4x$
   $(f \circ g)(x) = f(g(x))$
   $= f(5-4x)$
   $= \sqrt{3-2\cdot(5-4x)}$
   $= \sqrt{3-10+8x}$
   $= \sqrt{8x-7}$
   Domain:
   $8x-7 \geq 0 \quad \Rightarrow 8x \geq 7 \quad \Rightarrow x \geq \frac{7}{8}$
   $D = [\frac{7}{8}, \infty)$

9. $f(x) = \sqrt{3-2x}$
   $g(x) = 5-4x$
   $(g \circ f)(x) = g(f(x))$
   $= g(\sqrt{3-2x})$
   $= 5 - 4\cdot\sqrt{3-2x}$
   Domain:
   $3-2x \geq 0 \quad \Rightarrow -2x \geq -3 \quad \Rightarrow x \leq \frac{3}{2}$
   $D = (-\infty, \frac{3}{2}]$

10. $f(x) = \frac{1}{x^2-x-12}$
    $g(x) = 3x-5$
    $(g \circ f)(x) = g(f(x))$
    $= g(\frac{1}{x^2-x-12}) = 3 \cdot \frac{1}{x^2-x-12} - 5$
    $= \frac{3}{x^2-x-12} - \frac{5(x^2-x-12)}{x^2-x-12}$
    $= \frac{3-5x^2+5x+60}{x^2-x-12} = \frac{-5x^2+5x+63}{x^2-x-12}$
    Domain:
    $x^2-x-12=0$
    $\Rightarrow (x+3)(x-4)=0 \quad \Rightarrow x=-3, x=4$
    $D = \mathbb{R} - \{-3, 4\}$

11. $f(x) = \frac{1}{x^2-x-12}$
    $g(x) = 3x-5$
    $(f \circ g)(x) =$

Find the compositions and state their domains.

8. $f(x) = \sqrt{3-2x}$
$g(x) = 5 - 4x$
$(f \circ g)(x) = f(g(x))$
$= f(5-4x)$
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$= \sqrt{3 - 10 + 8x}$
$= \sqrt{8x-7}$
Domain:
$8x - 7 \geq 0 \quad \Rightarrow 8x \geq 7 \quad \Rightarrow x \geq \frac{7}{8}$
$D = [\frac{7}{8}, \infty)$

9. $f(x) = \sqrt{3-2x}$
$g(x) = 5 - 4x$
$(g \circ f)(x) = g(f(x))$
$= g(\sqrt{3-2x})$
$= 5 - 4\cdot\sqrt{3-2x}$
Domain:
$3 - 2x \geq 0 \quad \Rightarrow -2x \geq -3 \quad \Rightarrow x \leq \frac{3}{2}$
$D = (-\infty, \frac{3}{2}]$

10. $f(x) = \frac{1}{x^2-x-12}$
$g(x) = 3x - 5$
$(g \circ f)(x) = g(f(x))$
$= g(\frac{1}{x^2-x-12}) = 3 \cdot \frac{1}{x^2-x-12} - 5$
$= \frac{3}{x^2-x-12} - \frac{5(x^2-x-12)}{x^2-x-12}$
$= \frac{3-5x^2+5x+60}{x^2-x-12} = \frac{-5x^2+5x+63}{x^2-x-12}$
Domain:
$x^2 - x - 12 = 0$
$\Rightarrow (x+3)(x-4) = 0 \quad \Rightarrow x = -3, x = 4$
$D = \mathbb{R} - \{-3, 4\}$

11. $f(x) = \frac{1}{x^2-x-12} = \frac{1}{(x+3)(x-4)}$
$g(x) = 3x - 5$
$(f \circ g)(x) = f(g(x)) = f(3x-5)$
$= \frac{1}{((3x-5)+3)\cdot((3x-5)-4)} = \frac{1}{(3x-2)(3x-9)}$
Domain:
$3x - 2 = 0$ or $3x - 9 = 0$
$\Rightarrow x = \frac{2}{3}$ or $x = 3 \quad \Rightarrow D = \mathbb{R} - \{\frac{2}{3}, 3\}$