Chapter 2
Functions and Graphs

Section 2.1

Check Point Exercises

1. The domain is the set of all first components: {0, 10, 20, 30, 40}. The range is the set of all second components: {9.1, 6.7, 10.7, 13.2, 21.2}.

2. **a.** The relation is not a function since the two ordered pairs (5, 6) and (5, 8) have the same first component but different second components.

b. The relation is a function since no two ordered pairs have the same first component and different second components.

3. **a.** $2x+y=6$

$$y=6-2x$$

For each value of *x*, there is one and only one value for *y*, so the equation defines *y* as a function of *x*.

b. $x^2+y^2=1$

$$y^2=1-x^2$$

$$y=\pm\sqrt{1-x^2}$$

Since there are values of *x* (all values between –1 and 1 exclusive) that give more than one value for *y* (for example, if *x* = 0, then $y=\pm\sqrt{1-0^2}=\pm 1$), the equation does not define *y* as a function of *x*.

4. **a.**
$$\begin{aligned} f(-5) &= (-5)^2-2(-5)+7 \\ &= 25-(-10)+7 \\ &= 42 \end{aligned}$$

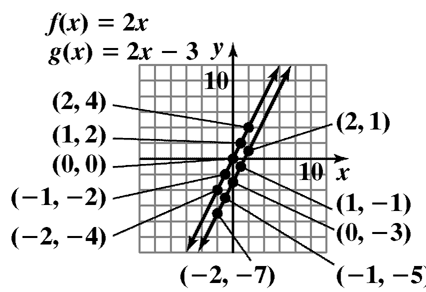
b.
$$\begin{aligned} f(x+4) &= (x+4)^2-2(x+4)+7 \\ &= x^2+8x+16-2x-8+7 \\ &= x^2+6x+15 \end{aligned}$$

c.
$$\begin{aligned} f(-x) &= (-x)^2-2(-x)+7 \\ &= x^2-(-2x)+7 \\ &= x^2+2x+7 \end{aligned}$$

5.

x	$f(x)=2x$	(x,y)
-2	–4	$(-2,-4)$
-1	–2	$(-1,-2)$
0	0	$(0,0)$
1	2	$(1,2)$
2	4	$(2,4)$

x	$g(x)=2x-3$	(x,y)
-2	$g(-2)=2(-2)-3=-7$	$(-2,-7)$
-1	$g(-1)=2(-1)-3=-5$	$(-1,-5)$
0	$g(0)=2(0)-3=-3$	$(0,-3)$
1	$g(1)=2(1)-3=-1$	$(1,-1)$
2	$g(2)=2(2)-3=1$	$(2,1)$



The graph of *g* is the graph of *f* shifted down 3 units.

6. The graph (a) passes the vertical line test and is therefore is a function.
The graph (b) fails the vertical line test and is therefore not a function.
The graph (c) passes the vertical line test and is therefore is a function.
The graph (d) fails the vertical line test and is therefore not a function.

7. **a.** $f(5)=400$

b. $x=9$, $f(9)=100$

c. The minimum T cell count in the asymptomatic stage is approximately 425.

8. **a.** domain: $\{x|-2 \le x \le 1\}$ or $[-2,1]$.
range: $\{y|0 \le y \le 3\}$ or $[0,3]$.

b. domain: $\{x|-2 < x \le 1\}$ or $(-2,1]$.
range: $\{y|-1 \le y < 2\}$ or $[-1,2)$.

c. domain: $\{x|-3 \le x < 0\}$ or $[-3,0)$.
range: $\{y|y = -3,-2,-1\}$.

Concept and Vocabulary Check 2.1

1. relation; domain; range

2. function

3. *f*; *x*

4. true

5. false

6. x; $x+6$

7. ordered pairs

8. more than once; function

9. $[0,3)$; domain

10. $[1,\infty)$; range

11. 0; 0; zeros

12. false

Exercise Set 2.1

1. The relation is a function since no two ordered pairs have the same first component and different second components. The domain is {1, 3, 5} and the range is {2, 4, 5}.

2. The relation is a function because no two ordered pairs have the same first component and different second components The domain is {4, 6, 8} and the range is {5, 7, 8}.

3. The relation is not a function since the two ordered pairs (3, 4) and (3, 5) have the same first component but different second components (the same could be said for the ordered pairs (4, 4) and (4, 5)). The domain is {3, 4} and the range is {4, 5}.

4. The relation is not a function since the two ordered pairs (5, 6) and (5, 7) have the same first component but different second components (the same could be said for the ordered pairs (6, 6) and (6, 7)). The domain is {5, 6} and the range is {6, 7}.

5. The relation is a function because no two ordered pairs have the same first component and different second components The domain is {3, 4, 5, 7} and the range is {–2, 1, 9}.

6. The relation is a function because no two ordered pairs have the same first component and different second components The domain is {–2, –1, 5, 10} and the range is {1, 4, 6}.

7. The relation is a function since there are no same first components with different second components. The domain is {–3, –2, –1, 0} and the range is {–3, –2, –1, 0}.

8. The relation is a function since there are no ordered pairs that have the same first component but different second components. The domain is {–7, –5, –3, 0} and the range is {–7, –5, –3, 0}.

9. The relation is not a function since there are ordered pairs with the same first component and different second components. The domain is {1} and the range is {4, 5, 6}.

10. The relation is a function since there are no two ordered pairs that have the same first component and different second components. The domain is {4, 5, 6} and the range is {1}.

11. $x + y = 16$
$y = 16 - x$
Since only one value of *y* can be obtained for each value of *x*, *y* is a function of *x*.

12. $x + y = 25$
$y = 25 - x$
Since only one value of *y* can be obtained for each value of *x*, *y* is a function of *x*.

13. $x^2 + y = 16$
$y = 16 - x^2$
Since only one value of *y* can be obtained for each value of *x*, *y* is a function of *x*.

14. $x^2 + y = 25$

$y = 25 - x^2$

Since only one value of y can be obtained for each value of x, y is a function of x.

15. $x^2 + y^2 = 16$

$y^2 = 16 - x^2$

$y = \pm\sqrt{16 - x^2}$

If $x = 0$, $y = \pm 4$.

Since two values, $y = 4$ and $y = -4$, can be obtained for one value of x, y is not a function of x.

16. $x^2 + y^2 = 25$

$y^2 = 25 - x^2$

$y = \pm\sqrt{25 - x^2}$

If $x = 0$, $y = \pm 5$.

Since two values, $y = 5$ and $y = -5$, can be obtained for one value of x, y is not a function of x.

17. $x = y^2$

$y = \pm\sqrt{x}$

If $x = 1$, $y = \pm 1$.

Since two values, $y = 1$ and $y = -1$, can be obtained for $x = 1$, y is not a function of x.

18. $4x = y2$

$y = \pm\sqrt{4x} = \pm 2\sqrt{x}$

If $x = 1$, then $y = \pm 2$.

Since two values, $y = 2$ and $y = -2$, can be obtained for $x = 1$, y is not a function of x.

19. $y = \sqrt{x + 4}$

Since only one value of y can be obtained for each value of x, y is a function of x.

20. $y = -\sqrt{x + 4}$

Since only one value of y can be obtained for each value of x, y is a function of x.

21. $x + y^3 = 8$

$y^3 = 8 - x$

$y = \sqrt[3]{8 - x}$

Since only one value of y can be obtained for each value of x, y is a function of x.

22. $x + y^3 = 27$

$y^3 = 27 - x$

$y = \sqrt[3]{27 - x}$

Since only one value of y can be obtained for each value of x, y is a function of x.

23. $xy + 2y = 1$

$y(x + 2) = 1$

$y = \dfrac{1}{x + 2}$

Since only one value of y can be obtained for each value of x, y is a function of x.

24. $xy - 5y = 1$

$y(x - 5) = 1$

$y = \dfrac{1}{x - 5}$

Since only one value of y can be obtained for each value of x, y is a function of x.

25. $|x| - y = 2$

$-y = -|x| + 2$

$y = |x| - 2$

Since only one value of y can be obtained for each value of x, y is a function of x.

26. $|x| - y = 5$

$-y = -|x| + 5$

$y = |x| - 5$

Since only one value of y can be obtained for each value of x, y is a function of x.

27. **a.** $f(6) = 4(6) + 5 = 29$

b. $f(x + 1) = 4(x + 1) + 5 = 4x + 9$

c. $f(-x) = 4(-x) + 5 = -4x + 5$

28. **a.** $f(4) = 3(4) + 7 = 19$

b. $f(x + 1) = 3(x + 1) + 7 = 3x + 10$

c. $f(-x) = 3(-x) + 7 = -3x + 7$

29. a. $g(-1) = (-1)^2 + 2(-1) + 3$
$= 1 - 2 + 3$
$= 2$

b. $g(x+5) = (x+5)^2 + 2(x+5) + 3$
$= x^2 + 10x + 25 + 2x + 10 + 3$
$= x^2 + 12x + 38$

c. $g(-x) = (-x)^2 + 2(-x) + 3$
$= x^2 - 2x + 3$

30. a. $g(-1) = (-1)^2 - 10(-1) - 3$
$= 1 + 10 - 3$
$= 8$

b. $g(x+2) = (x+2)^2 - 10(8+2) - 3$
$= x^2 + 4x + 4 - 10x - 20 - 3$
$= x^2 - 6x - 19$

c. $g(-x) = (-x)^2 - 10(-x) - 3$
$= x^2 + 10x - 3$

31. a. $h(2) = 2^4 - 2^2 + 1$
$= 16 - 4 + 1$
$= 13$

b. $h(-1) = (-1)^4 - (-1)^2 + 1$
$= 1 - 1 + 1$
$= 1$

c. $h(-x) = (-x)^4 - (-x)^2 + 1 = x^4 - x^2 + 1$

d. $h(3a) = (3a)^4 - (3a)^2 + 1$
$= 81a^4 - 9a^2 + 1$

32. a. $h(3) = 3^3 - 3 + 1 = 25$

b. $h(-2) = (-2)^3 - (-2) + 1$
$= -8 + 2 + 1$
$= -5$

c. $h(-x) = (-x)^3 - (-x) + 1 = -x^3 + x + 1$

d. $h(3a) = (3a)^3 - (3a) + 1$
$= 27a^3 - 3a + 1$

33. a. $f(-6) = \sqrt{-6+6} + 3 = \sqrt{0} + 3 = 3$

b. $f(10) = \sqrt{10+6} + 3$
$= \sqrt{16} + 3$
$= 4 + 3$
$= 7$

c. $f(x-6) = \sqrt{x-6+6} + 3 = \sqrt{x} + 3$

34. a. $f(16) = \sqrt{25-16} - 6 = \sqrt{9} - 6 = 3 - 6 = -3$

b. $f(-24) = \sqrt{25-(-24)} - 6$
$= \sqrt{49} - 6$
$= 7 - 6 = 1$

c. $f(25-2x) = \sqrt{25-(25-2x)} - 6$
$= \sqrt{2x} - 6$

35. a. $f(2) = \dfrac{4(2)^2 - 1}{2^2} = \dfrac{15}{4}$

b. $f(-2) = \dfrac{4(-2)^2 - 1}{(-2)^2} = \dfrac{15}{4}$

c. $f(-x) = \dfrac{4(-x)^2 - 1}{(-x)^2} = \dfrac{4x^2 - 1}{x^2}$

36. a. $f(2) = \dfrac{4(2)^3 + 1}{2^3} = \dfrac{33}{8}$

b. $f(-2) = \dfrac{4(-2)^3 + 1}{(-2)^3} = \dfrac{-31}{-8} = \dfrac{31}{8}$

c. $f(-x) = \dfrac{4(-x)^3 + 1}{(-x)^3} = \dfrac{-4x^3 + 1}{-x^3}$
or $\dfrac{4x^3 - 1}{x^3}$

37. a. $f(6) = \dfrac{6}{|6|} = 1$

b. $f(-6) = \dfrac{-6}{|-6|} = \dfrac{-6}{6} = -1$

c. $f(r^2) = \dfrac{r^2}{|r^2|} = \dfrac{r^2}{r^2} = 1$

38. **a.** $f(5)=\dfrac{|5+3|}{5+3}=\dfrac{|8|}{8}=1$

b. $f(-5)=\dfrac{|-5+3|}{-5+3}=\dfrac{|-2|}{-2}=\dfrac{2}{-2}=-1$

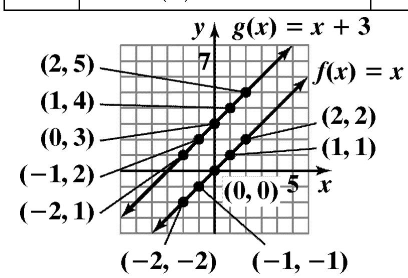
c. $f(-9-x)=\dfrac{|-9-x+3|}{-9-x+3}$

$=\dfrac{|-x-6|}{-x-6}=\begin{cases}1, \text{ if } x<-6\\ -1, \text{if } x>-6\end{cases}$

39.

x	$f(x)=x$	(x,y)
–2	$f(-2)=-2$	$(-2,-2)$
–1	$f(-1)=-1$	$(-1,-1)$
0	$f(0)=0$	$(0,0)$
1	$f(1)=1$	$(1,1)$
2	$f(2)=2$	$(2,2)$

x	$g(x)=x+3$	(x,y)
–2	$g(-2)=-2+3=1$	$(-2,1)$
–1	$g(-1)=-1+3=2$	$(-1,2)$
0	$g(0)=0+3=3$	$(0,3)$
1	$g(1)=1+3=4$	$(1,4)$
2	$g(2)=2+3=5$	$(2,5)$

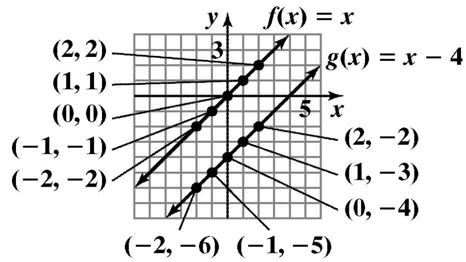


The graph of g is the graph of f shifted up 3 units.

40.

x	$f(x)=x$	(x,y)
–2	$f(-2)=-2$	$(-2,-2)$
–1	$f(-1)=-1$	$(-1,-1)$
0	$f(0)=0$	$(0,0)$
1	$f(1)=1$	$(1,1)$
2	$f(2)=2$	$(2,2)$

x	$g(x)=x-4$	(x,y)
–2	$g(-2)=-2-4=-6$	$(-2,-6)$
–1	$g(-1)=-1-4=-5$	$(-1,-5)$
0	$g(0)=0-4=-4$	$(0,-4)$
1	$g(1)=1-4=-3$	$(1,-3)$
2	$g(2)=2-4=-2$	$(2,-2)$

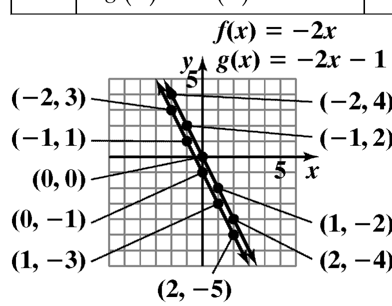


The graph of g is the graph of f shifted down 4 units.

41.

x	$f(x)=-2x$	(x,y)
–2	$f(-2)=-2(-2)=4$	$(-2,4)$
–1	$f(-1)=-2(-1)=2$	$(-1,2)$
0	$f(0)=-2(0)=0$	$(0,0)$
1	$f(1)=-2(1)=-2$	$(1,-2)$
2	$f(2)=-2(2)=-4$	$(2,-4)$

x	$g(x)=-2x-1$	(x,y)
–2	$g(-2)=-2(-2)-1=3$	$(-2,3)$
–1	$g(-1)=-2(-1)-1=1$	$(-1,1)$
0	$g(0)=-2(0)-1=-1$	$(0,-1)$
1	$g(1)=-2(1)-1=-3$	$(1,-3)$
2	$g(2)=-2(2)-1=-5$	$(2,-5)$

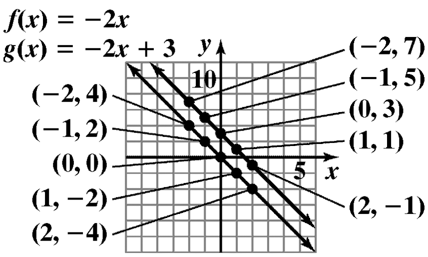


The graph of g is the graph of f shifted down 1 unit.

42.

x	$f(x) = -2x$	(x, y)
-2	$f(-2) = -2(-2) = 4$	$(-2, 4)$
-1	$f(-1) = -2(-1) = 2$	$(-1, 2)$
0	$f(0) = -2(0) = 0$	$(0, 0)$
1	$f(1) = -2(1) = -2$	$(1, -2)$
2	$f(2) = -2(2) = -4$	$(2, -4)$

x	$g(x) = -2x + 3$	(x, y)
-2	$g(-2) = -2(-2) + 3 = 7$	$(-2, 7)$
-1	$g(-1) = -2(-1) + 3 = 5$	$(-1, 5)$
0	$g(0) = -2(0) + 3 = 3$	$(0, 3)$
1	$g(1) = -2(1) + 3 = 1$	$(1, 1)$
2	$g(2) = -2(2) + 3 = -1$	$(2, -1)$

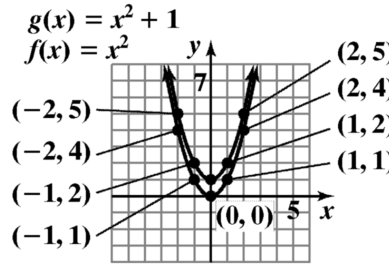


The graph of g is the graph of f shifted up 3 units.

43.

x	$f(x) = x^2$	(x, y)
-2	$f(-2) = (-2)^2 = 4$	$(-2, 4)$
-1	$f(-1) = (-1)^2 = 1$	$(-1, 1)$
0	$f(0) = (0)^2 = 0$	$(0, 0)$
1	$f(1) = (1)^2 = 1$	$(1, 1)$
2	$f(2) = (2)^2 = 4$	$(2, 4)$

x	$g(x) = x^2 + 1$	(x, y)
-2	$g(-2) = (-2)^2 + 1 = 5$	$(-2, 5)$
-1	$g(-1) = (-1)^2 + 1 = 2$	$(-1, 2)$
0	$g(0) = (0)^2 + 1 = 1$	$(0, 1)$
1	$g(1) = (1)^2 + 1 = 2$	$(1, 2)$
2	$g(2) = (2)^2 + 1 = 5$	$(2, 5)$

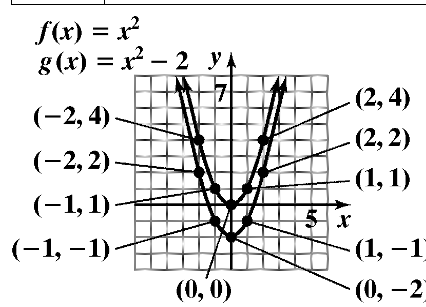


The graph of g is the graph of f shifted up 1 unit.

44.

x	$f(x) = x^2$	(x, y)
-2	$f(-2) = (-2)^2 = 4$	$(-2, 4)$
-1	$f(-1) = (-1)^2 = 1$	$(-1, 1)$
0	$f(0) = (0)^2 = 0$	$(0, 0)$
1	$f(1) = (1)^2 = 1$	$(1, 1)$
2	$f(2) = (2)^2 = 4$	$(2, 4)$

x	$g(x) = x^2 - 2$	(x, y)
-2	$g(-2) = (-2)^2 - 2 = 2$	$(-2, 2)$
-1	$g(-1) = (-1)^2 - 2 = -1$	$(-1, -1)$
0	$g(0) = (0)^2 - 2 = -2$	$(0, -2)$
1	$g(1) = (1)^2 - 2 = -1$	$(1, -1)$
2	$g(2) = (2)^2 - 2 = 2$	$(2, 2)$

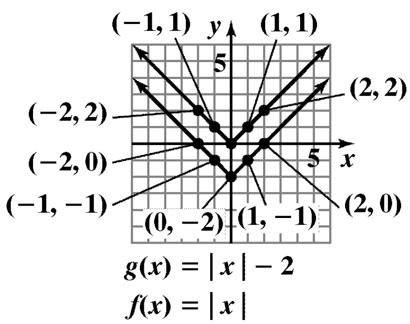


The graph of g is the graph of f shifted down 2 units.

45.

x	$f(x)=\lvert x\rvert$	(x,y)
-2	$f(-2)=\lvert -2\rvert=2$	$(-2,2)$
-1	$f(-1)=\lvert -1\rvert=1$	$(-1,1)$
0	$f(0)=\lvert 0\rvert=0$	$(0,0)$
1	$f(1)=\lvert 1\rvert=1$	$(1,1)$
2	$f(2)=\lvert 2\rvert=2$	$(2,2)$

x	$g(x)=\lvert x\rvert-2$	(x,y)
-2	$g(-2)=\lvert -2\rvert-2=0$	$(-2,0)$
-1	$g(-1)=\lvert -1\rvert-2=-1$	$(-1,-1)$
0	$g(0)=\lvert 0\rvert-2=-2$	$(0,-2)$
1	$g(1)=\lvert 1\rvert-2=-1$	$(1,-1)$
2	$g(2)=\lvert 2\rvert-2=0$	$(2,0)$

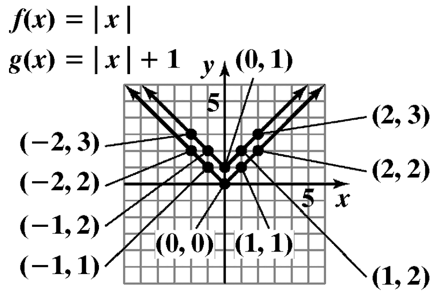


The graph of g is the graph of f shifted down 2 units.

46.

x	$f(x)=\lvert x\rvert$	(x,y)
-2	$f(-2)=\lvert -2\rvert=2$	$(-2,2)$
-1	$f(-1)=\lvert -1\rvert=1$	$(-1,1)$
0	$f(0)=\lvert 0\rvert=0$	$(0,0)$
1	$f(1)=\lvert 1\rvert=1$	$(1,1)$
2	$f(2)=\lvert 2\rvert=2$	$(2,2)$

x	$g(x)=\lvert x\rvert+1$	(x,y)
-2	$g(-2)=\lvert -2\rvert+1=3$	$(-2,3)$
-1	$g(-1)=\lvert -1\rvert+1=2$	$(-1,2)$
0	$g(0)=\lvert 0\rvert+1=1$	$(0,1)$
1	$g(1)=\lvert 1\rvert+1=2$	$(1,2)$
2	$g(2)=\lvert 2\rvert+1=3$	$(2,3)$

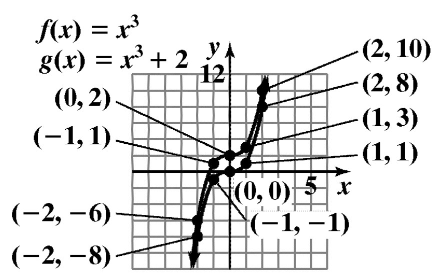


The graph of g is the graph of f shifted up 1 unit.

47.

x	$f(x)=x^3$	(x,y)
-2	$f(-2)=(-2)^3=-8$	$(-2,-8)$
-1	$f(-1)=(-1)^3=-1$	$(-1,-1)$
0	$f(0)=(0)^3=0$	$(0,0)$
1	$f(1)=(1)^3=1$	$(1,1)$
2	$f(2)=(2)^3=8$	$(2,8)$

x	$g(x)=x^3+2$	(x,y)
-2	$g(-2)=(-2)^3+2=-6$	$(-2,-6)$
-1	$g(-1)=(-1)^3+2=1$	$(-1,1)$
0	$g(0)=(0)^3+2=2$	$(0,2)$
1	$g(1)=(1)^3+2=3$	$(1,3)$
2	$g(2)=(2)^3+2=10$	$(2,10)$

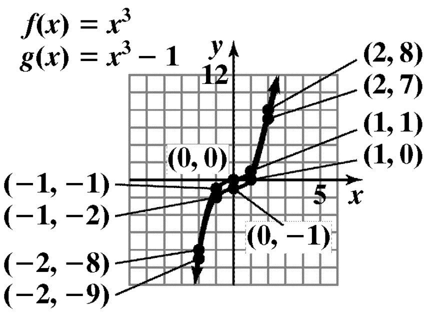


The graph of g is the graph of f shifted up 2 units.

48.

x	$f(x)=x^3$	(x,y)
–2	$f(-2)=(-2)^3=-8$	$(-2,-8)$
–1	$f(-1)=(-1)^3=-1$	$(-1,-1)$
0	$f(0)=(0)^3=0$	$(0,0)$
1	$f(1)=(1)^3=1$	$(1,1)$
2	$f(2)=(2)^3=8$	$(2,8)$

x	$g(x)=x^3-1$	(x,y)
–2	$g(-2)=(-2)^3-1=-9$	$(-2,-9)$
–1	$g(-1)=(-1)^3-1=-2$	$(-1,-2)$
0	$g(0)=(0)^3-1=-1$	$(0,-1)$
1	$g(1)=(1)^3-1=0$	$(1,0)$
2	$g(2)=(2)^3-1=7$	$(2,7)$

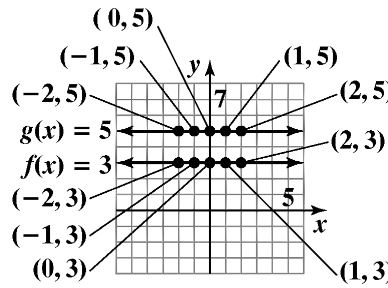


The graph of g is the graph of f shifted down 1 unit.

49.

x	$f(x)=3$	(x,y)
–2	$f(-2)=3$	$(-2,3)$
–1	$f(-1)=3$	$(-1,3)$
0	$f(0)=3$	$(0,3)$
1	$f(1)=3$	$(1,3)$
2	$f(2)=3$	$(2,3)$

x	$g(x)=5$	(x,y)
–2	$g(-2)=5$	$(-2,5)$
–1	$g(-1)=5$	$(-1,5)$
0	$g(0)=5$	$(0,5)$
1	$g(1)=5$	$(1,5)$
2	$g(2)=5$	$(2,5)$

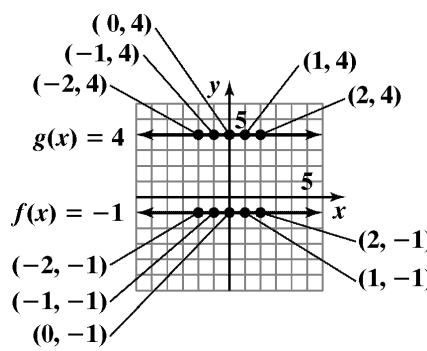


The graph of g is the graph of f shifted up 2 units.

50.

x	$f(x)=-1$	(x,y)
–2	$f(-2)=-1$	$(-2,-1)$
–1	$f(-1)=-1$	$(-1,-1)$
0	$f(0)=-1$	$(0,-1)$
1	$f(1)=-1$	$(1,-1)$
2	$f(2)=-1$	$(2,-1)$

x	$g(x)=4$	(x,y)
–2	$g(-2)=4$	$(-2,4)$
–1	$g(-1)=4$	$(-1,4)$
0	$g(0)=4$	$(0,4)$
1	$g(1)=4$	$(1,4)$
2	$g(2)=4$	$(2,4)$

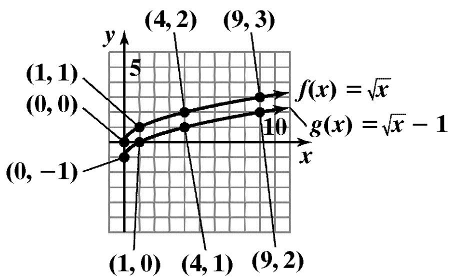


The graph of g is the graph of f shifted up 5 units.

51.

x	$f(x)=\sqrt{x}$	(x,y)
0	$f(0)=\sqrt{0}=0$	$(0,0)$
1	$f(1)=\sqrt{1}=1$	$(1,1)$
4	$f(4)=\sqrt{4}=2$	$(4,2)$
9	$f(9)=\sqrt{9}=3$	$(9,3)$

x	$g(x)=\sqrt{x}-1$	(x,y)
0	$g(0)=\sqrt{0}-1=-1$	$(0,-1)$
1	$g(1)=\sqrt{1}-1=0$	$(1,0)$
4	$g(4)=\sqrt{4}-1=1$	$(4,1)$
9	$g(9)=\sqrt{9}-1=2$	$(9,2)$

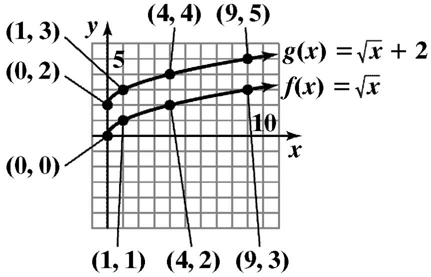


The graph of g is the graph of *f* shifted down 1 unit.

52.

x	$f(x)=\sqrt{x}$	(x,y)
0	$f(0)=\sqrt{0}=0$	$(0,0)$
1	$f(1)=\sqrt{1}=1$	$(1,1)$
4	$f(4)=\sqrt{4}=2$	$(4,2)$
9	$f(9)=\sqrt{9}=3$	$(9,3)$

x	$g(x)=\sqrt{x}+2$	(x,y)
0	$g(0)=\sqrt{0}+2=2$	$(0,2)$
1	$g(1)=\sqrt{1}+2=3$	$(1,3)$
4	$g(4)=\sqrt{4}+2=4$	$(4,4)$
9	$g(9)=\sqrt{9}+2=5$	$(9,5)$

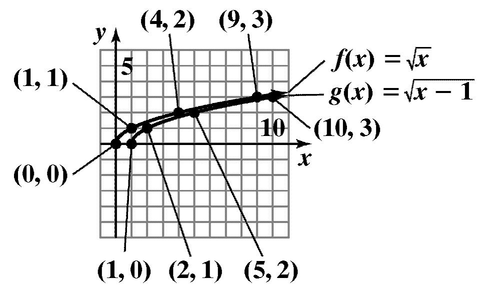


The graph of g is the graph of *f* shifted up 2 units.

53.

x	$f(x)=\sqrt{x}$	(x,y)
0	$f(0)=\sqrt{0}=0$	$(0,0)$
1	$f(1)=\sqrt{1}=1$	$(1,1)$
4	$f(4)=\sqrt{4}=2$	$(4,2)$
9	$f(9)=\sqrt{9}=3$	$(9,3)$

x	$g(x)=\sqrt{x-1}$	(x,y)
1	$g(1)=\sqrt{1-1}=0$	$(1,0)$
2	$g(2)=\sqrt{2-1}=1$	$(2,1)$
5	$g(5)=\sqrt{5-1}=2$	$(5,2)$
10	$g(10)=\sqrt{10-1}=3$	$(10,3)$

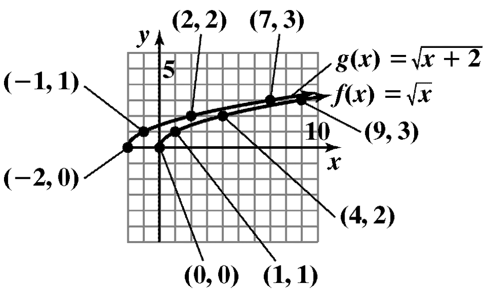


The graph of g is the graph of *f* shifted right 1 unit.

54.

x	$f(x)=\sqrt{x}$	(x,y)
0	$f(0)=\sqrt{0}=0$	$(0,0)$
1	$f(1)=\sqrt{1}=1$	$(1,1)$
4	$f(4)=\sqrt{4}=2$	$(4,2)$
9	$f(9)=\sqrt{9}=3$	$(9,3)$

x	$g(x)=\sqrt{x+2}$	(x,y)
–2	$g(-2)=\sqrt{-2+2}=0$	$(-2,0)$
–1	$g(-1)=\sqrt{-1+2}=1$	$(-1,1)$
2	$g(2)=\sqrt{2+2}=2$	$(2,2)$
7	$g(7)=\sqrt{7+2}=3$	$(7,3)$



The graph of g is the graph of *f* shifted left 2 units.

55. function

56. function

57. function

58. not a function

59. not a function

60. not a function

61. function

62. not a function

63. function

64. function

65. $f(-2)=-4$

66. $f(2)=-4$

67. $f(4)=4$

68. $f(-4)=4$

69. $f(-3)=0$

70. $f(-1)=0$

71. $g(-4)=2$

72. $g(2)=-2$

73. $g(-10)=2$

74. $g(10)=-2$

75. When $x=-2$, $g(x)=1$.

76. When $x=1$, $g(x)=-1$.

77. **a.** domain: $(-\infty,\infty)$

b. range: $[-4,\infty)$

c. x-intercepts: –3 and 1

d. y-intercept: –3

e. $f(-2)=-3$ and $f(2)=5$

78. **a.** domain: $(-\infty,\infty)$

b. range: $(-\infty, 4]$

c. x-intercepts: –3 and 1

d. y-intercept: 3

e. $f(-2)=3$ and $f(2)=-5$

79. **a.** domain: $(-\infty,\infty)$

b. range: $[1,\infty)$

c. x-intercept: none

d. y-intercept: 1

e. $f(-1)=2$ and $f(3)=4$

80. **a.** domain: $(-\infty, \infty)$

b. range: $[0, \infty)$

c. x-intercept: -1

d. y-intercept: 1

e. $f(-4) = 3$ and $f(3) = 4$

81. **a.** domain: $[0, 5)$

b. range: $[-1, 5)$

c. x-intercept: 2

d. y-intercept: -1

e. $f(3) = 1$

82. **a.** domain: $(-6, 0]$

b. range: $[-3, 4)$

c. x-intercept: -3.75

d. y-intercept: -3

e. $f(-5) = 2$

83. **a.** domain: $[0, \infty)$

b. range: $[1, \infty)$

c. x-intercept: none

d. y-intercept: 1

e. $f(4) = 3$

84. **a.** domain: $[-1, \infty)$

b. range: $[0, \infty)$

c. x-intercept: -1

d. y-intercept: 1

e. $f(3) = 2$

85. **a.** domain: $[-2, 6]$

b. range: $[-2, 6]$

c. x-intercept: 4

d. y-intercept: 4

e. $f(-1) = 5$

86. **a.** domain: $[-3, 2]$

b. range: $[-5, 5]$

c. x-intercept: $-\frac{1}{2}$

d. y-intercept: 1

e. $f(-2) = -3$

87. **a.** domain: $(-\infty, \infty)$

b. range: $(-\infty, -2]$

c. x-intercept: none

d. y-intercept: -2

e. $f(-4) = -5$ and $f(4) = -2$

88. **a.** domain: $(-\infty, \infty)$

b. range: $[0, \infty)$

c. x-intercept: $\{x \mid x \leq 0\}$

d. y-intercept: 0

e. $f(-2) = 0$ and $f(2) = 4$

89. **a.** domain: $(-\infty, \infty)$

b. range: $(0, \infty)$

c. x-intercept: none

d. y-intercept: 1.5

e. $f(4) = 6$

90. **a.** domain: $(-\infty, 1) \cup (1, \infty)$

b. range: $(-\infty, 0) \cup (0, \infty)$

c. x-intercept: none

d. y-intercept: -1

e. $f(2) = 1$

91. **a.** domain: $\{-5, -2, 0, 1, 3\}$

b. range: $\{2\}$

c. x-intercept: none

d. y-intercept: 2

e. $f(-5) + f(3) = 2 + 2 = 4$

92. **a.** domain: {–5, –2, 0, 1, 4}

b. range: {–2}

c. x-intercept: none

d. y-intercept: –2

e. $f(-5)+f(4)=-2+(-2)=-4$

93. $g(1)=3(1)-5=3-5=-2$

$$f(g(1))=f(-2)=(-2)^2-(-2)+4$$
$$=4+2+4=10$$

94. $g(-1)=3(-1)-5=-3-5=-8$

$$f(g(-1))=f(-8)=(-8)^2-(-8)+4$$
$$=64+8+4=76$$

95. $\sqrt{3-(-1)}-(-6)^2+6\div(-6)\cdot 4$

$$=\sqrt{3+1}-36+6\div(-6)\cdot 4$$
$$=\sqrt{4}-36+-1\cdot 4$$
$$=2-36+-4$$
$$=-34+-4$$
$$=-38$$

96. $|-4-(-1)|-(-3)^2+-3\div 3\cdot -6$

$$=|-4+1|-9+-3\div 3\cdot -6$$
$$=|-3|-9+-1\cdot -6$$
$$=3-9+6=-6+6=0$$

97. $f(-x)-f(x)$

$$=(-x)^3+(-x)-5-(x^3+x-5)$$
$$=-x^3-x-5-x^3-x+5=-2x^3-2x$$

98. $f(-x)-f(x)$

$$=(-x)^2-3(-x)+7-(x^2-3x+7)$$
$$=x^2+3x+7-x^2+3x-7$$
$$=6x$$

99. **a.** {(Philippines, 12), (Spain, 13), (Italy, 14), (Germany, 14), (Russia, 16)}

b. Yes, the relation is a function. Each country (element in the domain) corresponds to only one age (element in the range).

c. {(12, Philippines), (13, Spain), (14, Italy), (14, Germany), (16, Russia)}

d. No, the relation is not a function. 14 in the domain corresponds to two members in the range, Italy and Germany.

100. **a.** {(Philippines, 18), (Spain, 18), (Italy, 16), (Germany, 16), (Russia, 16)}

b. Yes, the relation is a function. Each country (element in the domain) corresponds to only one age (element in the range).

c. {(18, Philippines), (18, Spain), (16, Italy), (16, Germany), (16, Russia)}

d. No, the relation is not a function. 18 in the domain corresponds to two members of the range, Philippines and Spain, and 16 in the domain corresponds to three members of the range, Italy, Germany, and Russia.

101. **a.** $f(70)=83$ which means the chance that a 60-year old will survive to age 70 is 83%.

b. $g(70)=76$ which means the chance that a 60-year old will survive to age 70 is 76%.

c. Function f is the better model.

102. **a.** $f(90)=25$ which means the chance that a 60-year old will survive to age 90 is 25%.

b. $g(90)=10$ which means the chance that a 60-year old will survive to age 90 is 10%.

c. Function f is the better model.

103. **a.** $G(30)=-0.01(30)^2+(30)+60=81$
In 2010, the wage gap was 81%. This is represented as $(30, 81)$ on the graph.

b. $G(30)$ underestimates the actual data shown by the bar graph by 2%.

104. **a.** $G(10) = -0.01(10)^2 + (10) + 60 = 69$
In 1990, the wage gap was 69%. This is represented as $(10, 69)$ on the graph.

b. $G(10)$ underestimates the actual data shown by the bar graph by 2%.

105. $C(x) = 100,000 + 100x$
$C(90) = 100,000 + 100(90) = \$109,000$
It will cost $109,000 to produce 90 bicycles.

106. $V(x) = 22,500 - 3200x$
$V(3) = 22,500 - 3200(3) = \$12,900$
After 3 years, the car will be worth $12,900.

107. $T(x) = \frac{40}{x} + \frac{40}{x+30}$
$T(30) = \frac{40}{30} + \frac{40}{30+30}$
$= \frac{80}{60} + \frac{40}{60}$
$= \frac{120}{60}$
$= 2$
If you travel 30 mph going and 60 mph returning, your total trip will take 2 hours.

108. $S(x) = 0.10x + 0.60(50 - x)$
$S(30) = 0.10(30) + 0.60(50 - 30) = 15$
When 30 mL of the 10% mixture is mixed with 20 mL of the 60% mixture, there will be 15 mL of sodium-iodine in the vaccine.

109. – 117. Answers will vary.

118. makes sense

119. does not make sense; Explanations will vary. Sample explanation: The parentheses used in function notation, such as $f(x)$, do not imply multiplication.

120. does not make sense; Explanations will vary. Sample explanation: The domain is the number of years worked for the company.

121. does not make sense; Explanations will vary. Sample explanation: This would not be a function because some elements in the domain would correspond to more than one age in the range.

122. false; Changes to make the statement true will vary. A sample change is: The domain is $[-4, 4]$.

123. false; Changes to make the statement true will vary. A sample change is: The range is $\left[-2, 2\right)$.

124. true

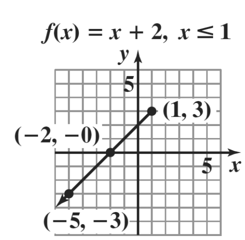
125. false; Changes to make the statement true will vary. A sample change is: $f(0) = 0.8$

126. $f(a+h) = 3(a+h) + 7 = 3a + 3h + 7$
$f(a) = 3a + 7$
$\frac{f(a+h) - f(a)}{h}$
$= \frac{(3a + 3h + 7) - (3a + 7)}{h}$
$= \frac{3a + 3h + 7 - 3a - 7}{h} = \frac{3h}{h} = 3$

127. Answers will vary.
An example is $\{(1,1),(2,1)\}$

128. It is given that $f(x+y) = f(x) + f(y)$ and $f(1) = 3$.
To find $f(2)$, rewrite 2 as 1 + 1.
$f(2) = f(1+1) = f(1) + f(1)$
$= 3 + 3 = 6$
Similarly:
$f(3) = f(2+1) = f(2) + f(1)$
$= 6 + 3 = 9$
$f(4) = f(3+1) = f(3) + f(1)$
$= 9 + 3 = 12$
While $f(x+y) = f(x) + f(y)$ is true for this function, it is not true for all functions. It is not true for $f(x) = x^2$, for example.

129. $C(t) = 20 + 0.40(t - 60)$
$C(100) = 20 + 0.40(100 - 60)$
$= 20 + 0.40(40)$
$= 20 + 16$
$= 36$
For 100 calling minutes, the monthly cost is $36.

130.


131. $2(x+h)^2+3(x+h)+5-(2x^2+3x+5)$
$= 2(x^2+2xh+h^2)+3x+3h+5-2x^2-3x-5$
$= 2x^2+4xh+2h^2+3x+3h+5-2x^2-3x-5$
$= 2x^2-2x^2+4xh+2h^2+3x-3x+3h+5-5$
$= 4xh+2h^2+3h$

Section 2.2

Check Point Exercises

1. The function is increasing on the interval $(-\infty,-1)$, decreasing on the interval $(-1,1)$, and increasing on the interval $(1,\infty)$.

2. **a.** $f(-x)=(-x)^2+6=x^2+6=f(x)$
The function is even.

b. $g(-x)=7(-x)^3-(-x)=-7x^3+x=-f(x)$
The function is odd.

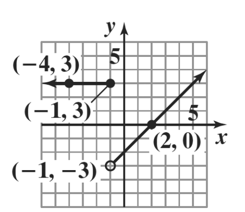
c. $h(-x)=(-x)^5+1=-x^5+1$
The function is neither even nor odd.

3. $C(t)=\begin{cases}20 & \text{if } 0\le t\le 60\\ 20+0.40(t-60) & \text{if } t>60\end{cases}$

b. Since $0\le 40\le 60$, $C(40)=20$
With 40 calling minutes, the cost is \$20.
This is represented by $(40,20)$.

c. Since $80>60$,
$C(80)=20+0.40(80-60)=28$
With 80 calling minutes, the cost is \$28.
This is represented by $(80,28)$.

4.



$f(x)=\begin{cases}3 & \text{if } x\le -1\\ x-2 & \text{if } x>-1\end{cases}$

5. **a.** $f(x)=-2x^2+x+5$
$f(x+h)=-2(x+h)^2+(x+h)+5$
$=-2(x^2+2xh+h^2)+x+h+5$
$=-2x^2-4xh-2h^2+x+h+5$

b. $\dfrac{f(x+h)-f(x)}{h}$
$=\dfrac{-2x^2-4xh-2h^2+x+h+5-\left(-2x^2+x+5\right)}{h}$
$=\dfrac{-2x^2-4xh-2h^2+x+h+5+2x^2-x-5}{h}$
$=\dfrac{-4xh-2h^2+h}{h}$
$=\dfrac{h\left(-4x-2h+1\right)}{h}$
$=-4x-2h+1,\quad h\ne 0$

Concept and Vocabulary Check 2.2

1. $<f(x_2)$; $>f(x_2)$; $=f(x_2)$

2. maximum; minimum

3. $f(x)$; y-axis

4. $-f(x)$; origin

5. piecewise

6. less than or equal to x; 2; -3; 0

7. difference quotient; $x+h$; $f(x)$; h; h

8. false

9. false

Exercise Set 2.2

1. **a.** increasing: $(-1,\infty)$

b. decreasing: $(-\infty,-1)$

c. constant: none

2. **a.** increasing: $(-\infty,-1)$

b. decreasing: $(-1,\infty)$

c. constant: none

3. **a.** increasing: $(0, \infty)$

b. decreasing: none

c. constant: none

4. **a.** increasing: $(-1, \infty)$

b. decreasing: none

c. constant: none

5. **a.** increasing: none

b. decreasing: $(-2, 6)$

c. constant: none

6. **a.** increasing: $(-3, 2)$

b. decreasing: none

c. constant: none

7. **a.** increasing: $(-\infty, -1)$

b. decreasing: none

c. constant: $(-1, \infty)$

8. **a.** increasing: $(0, \infty)$

b. decreasing: none

c. constant: $(-\infty, 0)$

9. **a.** increasing: $(-\infty, 0)$ or $(1.5, 3)$

b. decreasing: $(0, 1.5)$ or $(3, \infty)$

c. constant: none

10. **a.** increasing: $(-5, -4)$ or $(-2, 0)$ or $(2, 4)$

b. decreasing: $(-4, -2)$ or $(0, 2)$ or $(4, 5)$

c. constant: none

11. **a.** increasing: $(-2, 4)$

b. decreasing: none

c. constant: $(-\infty, -2)$ or $(4, \infty)$

12. **a.** increasing: none

b. decreasing: $(-4, 2)$

c. constant: $(-\infty, -4)$ or $(2, \infty)$

13. **a.** $x = 0$, relative maximum = 4

b. $x = -3, 3$, relative minimum = 0

14. **a.** $x = 0$, relative maximum = 2

b. $x = -3, 3$, relative minimum = -1

15. **a.** $x = -2$, relative maximum = 21

b. $x = 1$, relative minimum = -6

16. **a.** $x = 1$, relative maximum = 30

b. $x = 4$, relative minimum = 3

17. $f(x) = x^3 + x$
$f(-x) = (-x)^3 + (-x)$
$f(-x) = -x^3 - x = -(x^3 + x)$
$f(-x) = -f(x)$, odd function

18. $f(x) = x^3 - x$
$f(-x) = (-x)^3 - (-x)$
$f(-x) = -x^3 + x = -(x^3 - x)$
$f(-x) = -f(x)$, odd function

19. $g(x) = x^2 + x$
$g(-x) = (-x)^2 + (-x)$
$g(-x) = x^2 - x$, neither

20. $g(x) = x^2 - x$
$g(-x) = (-x)^2 - (-x)$
$g(-x) = x^2 + x$, neither

21. $h(x) = x^2 - x^4$
$h(-x) = (-x)^2 - (-x)^4$
$h(-x) = x^2 - x^4$
$h(-x) = h(x)$, even function

22. $h(x) = 2x^2 + x^4$
$h(-x) = 2(-x)^2 + (-x)^4$
$h(-x) = 2x^2 + x^4$
$h(-x) = h(x)$, even function

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

$f(-x)=(-x)^2-(-x)^4+1$

$f(-x)=x^2-x^4+1$

$f(-x)=f(x)$, even function

24. $f(x)=2x^2+x^4+1$

$f(-x)=2(-x)^2+(-x)^4+1$

$f(-x)=2x^2+x^4+1$

$f(-x)=f(x)$, even function

25. $f(x)=\frac{1}{5}x^6-3x^2$

$f(-x)=\frac{1}{5}(-x)^6-3(-x)^2$

$f(-x)=\frac{1}{5}x^6-3x^2$

$f(-x)=f(x)$, even function

26. $f(x)=2x^3-6x^5$

$f(-x)=2(-x)^3-6(-x)^5$

$f(-x)=-2x^3+6x^5$

$f(-x)=-(2x^3-6x^5)$

$f(-x)=-f(x)$, odd function

27. $f(x)=x\sqrt{1-x^2}$

$f(-x)=-x\sqrt{1-(-x)^2}$

$f(-x)=-x\sqrt{1-x^2}$

$=-\left(x\sqrt{1-x^2}\right)$

$f(-x)=-f(x)$, odd function

28. $f(x)=x^2\sqrt{1-x^2}$

$f(-x)=(-x)^2\sqrt{1-(-x)^2}$

$f(-x)=x^2\sqrt{1-x^2}$

$f(-x)=f(x)$, even function

29. The graph is symmetric with respect to the y-axis. The function is even.

30. The graph is symmetric with respect to the origin. The function is odd.

31. The graph is symmetric with respect to the origin. The function is odd.

32. The graph is not symmetric with respect to the y-axis or the origin. The function is neither even nor odd.

33. a. domain: $(-\infty,\infty)$

b. range: $[-4,\infty)$

c. x-intercepts: 1, 7

d. y-intercept: 4

e. $(4,\infty)$

f. $(0,4)$

g. $(-\infty,0)$

h. $x=4$

i. $y=-4$

j. $f(-3)=4$

k. $f(2)=-2$ and $f(6)=-2$

l. neither ; $f(-x)\neq x$, $f(-x)\neq -x$

34. a. domain: $(-\infty,\infty)$

b. range: $(-\infty,4]$

c. x-intercepts: –4, 4

d. y-intercept: 1

e. $(-\infty,-2)$ or $(0,3)$

f. $(-2,0)$ or $(3,\infty)$

g. $(-\infty,-4]$ or $[4,\infty)$

h. $x=-2$ and $x=3$

i. $f(-2)=4$ and $f(3)=2$

j. $f(-2)=4$

k. $x=-4$ and $x=4$

l. neither ; $f(-x)\neq x$, $f(-x)\neq -x$

35. **a.** domain: $(-\infty, 3]$

b. range: $(-\infty, 4]$

c. x-intercepts: –3, 3

d. $f(0) = 3$

e. $(-\infty, 1)$

f. $(1, 3)$

g. $(-\infty, -3]$

h. $f(1) = 4$

i. $x = 1$

j. positive; $f(-1) = +2$

36. **a.** domain: $(-\infty, 6]$

b. range: $(-\infty, 1]$

c. zeros of f: –3, 3

d. $f(0) = 1$

e. $(-\infty, -2)$

f. $(2, 6)$

g. $(-2, 2)$

h. $(-3, 3)$

i. $x = -5$ and $x = 5$

j. negative; $f(4) = -1$

k. neither

l. no; f(2) is not greater than the function values to the immediate left.

37. **a.** $f(-2) = 3(-2) + 5 = -1$

b. $f(0) = 4(0) + 7 = 7$

c. $f(3) = 4(3) + 7 = 19$

38. **a.** $f(-3) = 6(-3) - 1 = -19$

b. $f(0) = 7(0) + 3 = 3$

c. $f(4) = 7(4) + 3 = 31$

39. **a.** $g(0) = 0 + 3 = 3$

b. $g(-6) = -(-6 + 3) = -(-3) = 3$

c. $g(-3) = -3 + 3 = 0$

40. **a.** $g(0) = 0 + 5 = 5$

b. $g(-6) = -(-6 + 5) = -(-1) = 1$

c. $g(-5) = -5 + 5 = 0$

41. **a.** $h(5) = \dfrac{5^2 - 9}{5 - 3} = \dfrac{25 - 9}{2} = \dfrac{16}{2} = 8$

b. $h(0) = \dfrac{0^2 - 9}{0 - 3} = \dfrac{-9}{-3} = 3$

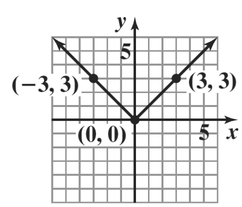
c. $h(3) = 6$

42. **a.** $h(7) = \dfrac{7^2 - 25}{7 - 5} = \dfrac{49 - 25}{2} = \dfrac{24}{2} = 12$

b. $h(0) = \dfrac{0^2 - 25}{0 - 5} = \dfrac{-25}{-5} = 5$

c. $h(5) = 10$

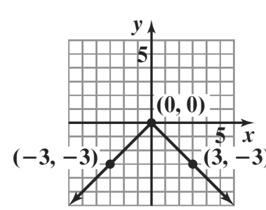
43. **a.**



$$f(x) = \begin{cases} -x & \text{if } x < 0 \\ x & \text{if } x \geq 0 \end{cases}$$

b. range: $[0, \infty)$

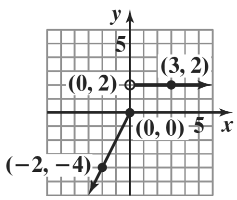
44. **a.**



$$f(x) = \begin{cases} x & \text{if } x < 0 \\ -x & \text{if } x \geq 0 \end{cases}$$

b. range: $(-\infty, 0]$

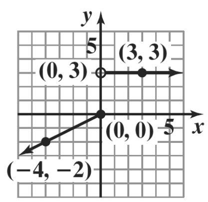
45. a.



$$f(x) = \begin{cases} 2x & \text{if } x \le 0 \\ 2 & \text{if } x > 0 \end{cases}$$

b. range: $(-\infty, 0] \cup \{2\}$

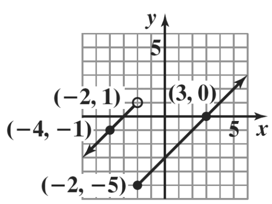
46. a.



$$f(x) = \begin{cases} \frac{1}{2}x & \text{if } x \le 0 \\ 3 & \text{if } x > 0 \end{cases}$$

b. range: $(-\infty, 0] \cup \{3\}$

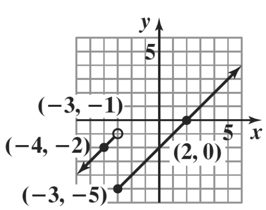
47. a.



$$f(x) = \begin{cases} x + 3 & \text{if } x < -2 \\ x - 3 & \text{if } x \ge -2 \end{cases}$$

b. range: $(-\infty, \infty)$

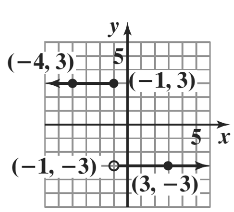
48. a.



$$f(x) = \begin{cases} x + 2 & \text{if } x < -3 \\ x - 2 & \text{if } x \ge -3 \end{cases}$$

b. range: $(-\infty, \infty)$

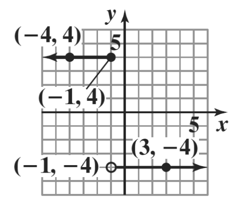
49. a.



$$f(x) = \begin{cases} 3 & \text{if } x \le -1 \\ -3 & \text{if } x > -1 \end{cases}$$

b. range: $\{-3, 3\}$

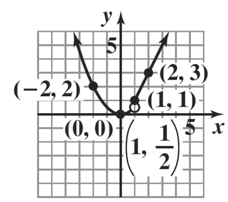
50. a.



$$f(x) = \begin{cases} 4 & \text{if } x \le -1 \\ -4 & \text{if } x > -1 \end{cases}$$

b. range: $\{-4, 4\}$

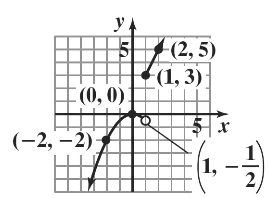
51. a.



$$f(x) = \begin{cases} \frac{1}{2}x^2 & \text{if } x < 1 \\ 2x - 1 & \text{if } x \ge 1 \end{cases}$$

b. range: $[0, \infty)$

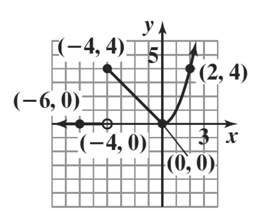
52. a.



$$f(x) = \begin{cases} -\frac{1}{2}x^2 & \text{if } x < 1 \\ 2x + 1 & \text{if } x \ge 1 \end{cases}$$

b. range: $(-\infty, 0] \cup [3, \infty)$

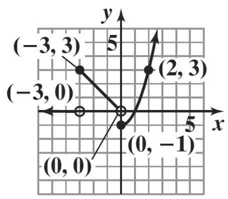
53. a.



$$f(x) = \begin{cases} 0 & \text{if } x < -4 \\ -x & \text{if } -4 \le x < 0 \\ x^2 & \text{if } x \ge 0 \end{cases}$$

b. range: $[0, \infty)$

54. **a.**



$$f(x) = \begin{cases} 0 & \text{if } x < -3 \\ -x & \text{if } -3 \le x < 0 \\ x^2 - 1 & \text{if } x \ge 0 \end{cases}$$

b. range: $[-1, \infty)$

55. $\frac{f(x+h)-f(x)}{h}$
$= \frac{4(x+h)-4x}{h}$
$= \frac{4x+4h-4x}{h}$
$= \frac{4h}{h}$
$= 4$

56. $\frac{f(x+h)-f(x)}{h}$
$= \frac{7(x+h)-7x}{h}$
$= \frac{7x+7h-7x}{h}$
$= \frac{7h}{h}$
$= 7$

57. $\frac{f(x+h)-f(x)}{h}$
$= \frac{3(x+h)+7-(3x+7)}{h}$
$= \frac{3x+3h+7-3x-7}{h}$
$= \frac{3h}{h}$
$= 3$

58. $\frac{f(x+h)-f(x)}{h}$
$= \frac{6(x+h)+1-(6x+1)}{h}$
$= \frac{6x+6h+1-6x-1}{h}$
$= \frac{6h}{h}$
$= 6$

59. $\frac{f(x+h)-f(x)}{h}$
$= \frac{(x+h)^2-x^2}{h}$
$= \frac{x^2+2xh+h^2-x^2}{h}$
$= \frac{2xh+h^2}{h}$
$= \frac{h(2x+h)}{h}$
$= 2x+h$

60. $\frac{f(x+h)-f(x)}{h}$
$= \frac{2(x+h)^2-2x^2}{h}$
$= \frac{2(x^2+2xh+h^2)-2x^2}{h}$
$= \frac{2x^2+4xh+2h^2-2x^2}{h}$
$= \frac{4xh+2h^2}{h}$
$= \frac{h(4x+2h)}{h}$
$= 4x+2h$

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

62. $\frac{f(x+h)-f(x)}{h}$
$=\frac{(x+h)^2-5(x+h)+8-(x^2-5x+8)}{h}$
$=\frac{x^2+2xh+h^2-5x-5h+8-x^2+5x-8}{h}$
$=\frac{2xh+h^2-5h}{h}$
$=\frac{h(2x+h-5)}{h}$
$=2x+h-5$

63. $\frac{f(x+h)-f(x)}{h}$
$=\frac{2(x+h)^2+(x+h)-1-(2x^2+x-1)}{h}$
$=\frac{2x^2+4xh+2h^2+x+h-1-2x^2-x+1}{h}$
$=\frac{4xh+2h^2+h}{h}$
$=\frac{h(4x+2h+1)}{h}$
$=4x+2h+1$

64. $\frac{f(x+h)-f(x)}{h}$
$=\frac{3(x+h)^2+(x+h)+5-(3x^2+x+5)}{h}$
$=\frac{3x^2+6xh+3h^2+x+h+5-3x^2-x-5}{h}$
$=\frac{6xh+3h^2+h}{h}$
$=\frac{h(6x+3h+1)}{h}$
$=6x+3h+1$

65. $\frac{f(x+h)-f(x)}{h}$
$=\frac{-(x+h)^2+2(x+h)+4-(-x^2+2x+4)}{h}$
$=\frac{-x^2-2xh-h^2+2x+2h+4+x^2-2x-4}{h}$
$=\frac{-2xh-h^2+2h}{h}$
$=\frac{h(-2x-h+2)}{h}$
$=-2x-h+2$

66. $\frac{f(x+h)-f(x)}{h}$
$=\frac{-(x+h)^2-3(x+h)+1-(-x^2-3x+1)}{h}$
$=\frac{-x^2-2xh-h^2-3x-3h+1+x^2+3x-1}{h}$
$=\frac{-2xh-h^2-3h}{h}$
$=\frac{h(-2x-h-3)}{h}$
$=-2x-h-3$

67. $\frac{f(x+h)-f(x)}{h}$
$=\frac{-2(x+h)^2+5(x+h)+7-(-2x^2+5x+7)}{h}$
$=\frac{-2x^2-4xh-2h^2+5x+5h+7+2x^2-5x-7}{h}$
$=\frac{-4xh-2h^2+5h}{h}$
$=\frac{h(-4x-2h+5)}{h}$
$=-4x-2h+5$

68. $\frac{f(x+h)-f(x)}{h}$

$$= \frac{-3(x+h)^2+2(x+h)-1-(-3x^2+2x-1)}{h}$$
$$= \frac{-3x^2-6xh-3h^2+2x+2h-1+3x^2-2x+1}{h}$$
$$= \frac{-6xh-3h^2+2h}{h}$$
$$= \frac{h(-6x-3h+2)}{h}$$
$$= -6x-3h+2$$

69. $\frac{f(x+h)-f(x)}{h}$

$$= \frac{-2(x+h)^2-(x+h)+3-(-2x^2-x+3)}{h}$$
$$= \frac{-2x^2-4xh-2h^2-x-h+3+2x^2+x-3}{h}$$
$$= \frac{-4xh-2h^2-h}{h}$$
$$= \frac{h(-4x-2h-1)}{h}$$
$$= -4x-2h-1$$

70. $\frac{f(x+h)-f(x)}{h}$

$$= \frac{-3(x+h)^2+(x+h)-1-(-3x^2+x-1)}{h}$$
$$= \frac{-3x^2-6xh-3h^2+x+h-1+3x^2-x+1}{h}$$
$$= \frac{-6xh-3h^2+h}{h}$$
$$= \frac{h(-6x-3h+1)}{h}$$
$$= -6x-3h+1$$

71. $\frac{f(x+h)-f(x)}{h} = \frac{6-6}{h} = \frac{0}{h} = 0$

72. $\frac{f(x+h)-f(x)}{h} = \frac{7-7}{h} = \frac{0}{h} = 0$

73. $\frac{f(x+h)-f(x)}{h}$

$$= \frac{\frac{1}{x+h}-\frac{1}{x}}{h}$$
$$= \frac{\frac{x}{x(x+h)}+\frac{-(x+h)}{x(x+h)}}{h}$$
$$= \frac{\frac{x-x-h}{x(x+h)}}{h}$$
$$= \frac{\frac{-h}{x(x+h)}}{h}$$
$$= \frac{-h}{x(x+h)}\cdot\frac{1}{h}$$
$$= \frac{-1}{x(x+h)}$$

74. $\frac{f(x+h)-f(x)}{h}$

$$= \frac{\frac{1}{2(x+h)}-\frac{1}{2x}}{h}$$
$$= \frac{\frac{x}{2x(x+h)}-\frac{x+h}{2x(x+h)}}{h}$$
$$= \frac{\frac{-h}{2x(x+h)}}{h}$$
$$= \frac{-h}{2x(x+h)}\cdot\frac{1}{h}$$
$$= \frac{-1}{2x(x+h)}$$

75. $\dfrac{f(x+h)-f(x)}{h}$

$=\dfrac{\sqrt{x+h}-\sqrt{x}}{h}$

$=\dfrac{\sqrt{x+h}-\sqrt{x}}{h}\cdot\dfrac{\sqrt{x+h}+\sqrt{x}}{\sqrt{x+h}+\sqrt{x}}$

$=\dfrac{x+h-x}{h\left(\sqrt{x+h}+\sqrt{x}\right)}$

$=\dfrac{h}{h\left(\sqrt{x+h}+\sqrt{x}\right)}$

$=\dfrac{1}{\sqrt{x+h}+\sqrt{x}}$

76. $\dfrac{f(x+h)-f(x)}{h}$

$=\dfrac{\sqrt{x+h-1}-\sqrt{x-1}}{h}$

$=\dfrac{\sqrt{x+h-1}-\sqrt{x-1}}{h}\cdot\dfrac{\sqrt{x+h-1}+\sqrt{x-1}}{\sqrt{x+h-1}+\sqrt{x-1}}$

$=\dfrac{x+h-1-(x-1)}{h\left(\sqrt{x+h-1}+\sqrt{x-1}\right)}$

$=\dfrac{x+h-1-x+1}{h\left(\sqrt{x+h-1}+\sqrt{x-1}\right)}$

$=\dfrac{h}{h\left(\sqrt{x+h-1}+\sqrt{x-1}\right)}$

$=\dfrac{1}{\sqrt{x+h-1}+\sqrt{x-1}}$

77. $\sqrt{f(-1.5)+f(-0.9)}-\left[f(\pi)\right]^2+f(-3)\div f(1)\cdot f(-\pi)$

$=\sqrt{1+0}-\left[-4\right]^2+2\div(-2)\cdot 3$

$=\sqrt{1}-16+(-1)\cdot 3$

$=1-16-3$

$=-18$

78. $\sqrt{f(-2.5)-f(1.9)}-\left[f(-\pi)\right]^2+f(-3)\div f(1)\cdot f(\pi)$

$\sqrt{f(-2.5)-f(1.9)}-\left[f(-\pi)\right]^2+f(-3)\div f(1)\cdot f(\pi)$

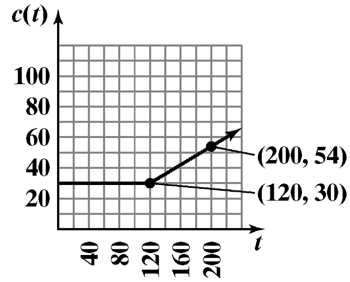
$=\sqrt{2-(-2)}-\left[3\right]^2+2\div(-2)\cdot(-4)$

$=\sqrt{4}-9+(-1)(-4)$

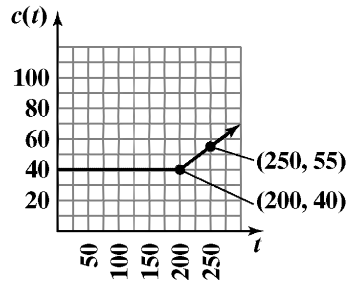
$=2-9+4$

$=-3$

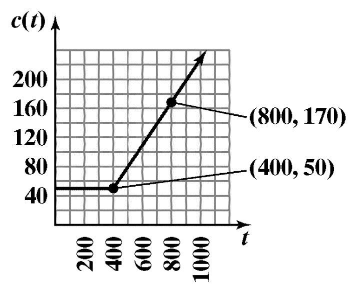
79. $30+0.30(t-120)=30+0.3t-36=0.3t-6$



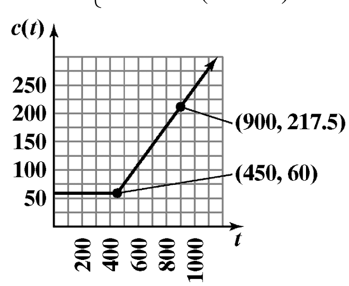
80. $40+0.30(t-200)=40+0.3t-60=0.3t-20$



81. $C(t)=\begin{cases}50 & \text{if } 0\le t\le 400\\ 50+0.30(t-400) & \text{if } t>400\end{cases}$



82. $C(t)=\begin{cases}60 & \text{if } 0\le t\le 450\\ 60+0.35(t-450) & \text{if } t>450\end{cases}$



83. increasing: (25, 55); decreasing: (55, 75)

84. increasing: (25, 65); decreasing: (65, 75)

85. The percent body fat in women reaches a maximum at age 55. This maximum is 38%.

86. The percent body fat in men reaches a maximum at age 65. This maximum is 26%.

87. domain: [25, 75]; range: [34, 38]

88. domain: [25, 75]; range: [23, 26]

89. This model describes percent body fat in men.

90. This model describes percent body fat in women.

91. $T(20,000) = 850 + 0.15(20,000 - 8500)$
$= 2575$
A single taxpayer with taxable income of $20,000 owes $2575.

92. $T(50,000) = 4750 + 0.25(50,000 - 34,500)$
$= 8625$
A single taxpayer with taxable income of $50,000 owes $8625.

93. $42,449 + 0.33(x - 174,400)$

94. $110,016.50 + 0.35(x - (x - 379,150)$

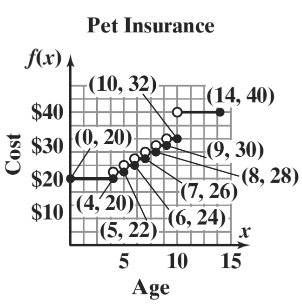
95. $f(3) = 0.85$
The cost of mailing a first-class letter weighing 3 ounces is $0.85.

96. $f(3.5) = 1.05$
The cost of mailing a first-class letter weighing 3.5 ounces is $1.05.

97. The cost to mail a letter weighing 1.5 ounces is $0.65.

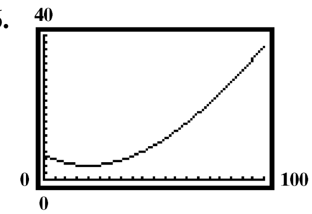
98. The cost to mail a letter weighing 1.8 ounces is $0.65.

99.



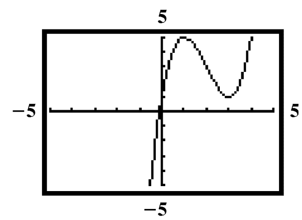
100. – 105. Answers will vary.

106.



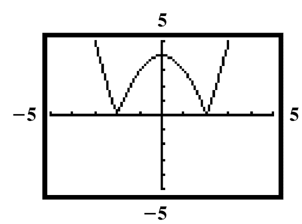
The number of doctor visits decreases during childhood and then increases as you get older.
The minimum is (20.29, 3.99), which means that the minimum number of doctor visits, about 4, occurs at around age 20.

107.



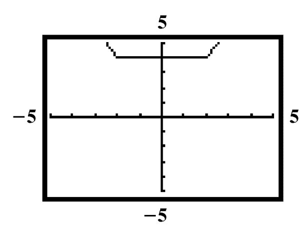
Increasing: $(-\infty, 1)$ or $(3, \infty)$
Decreasing: (1, 3)

108.



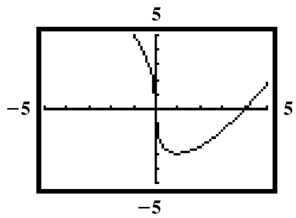
Increasing: (–2, 0) or (2, ∞)
Decreasing: (–∞, –2) or (0, 2)

109.



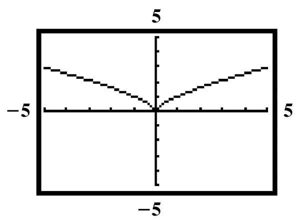
Increasing: $(2, \infty)$
Decreasing: $(-\infty, -2)$
Constant: (–2, 2)

110.



Increasing: $(1, \infty)$
Decreasing: $(-\infty, 1)$

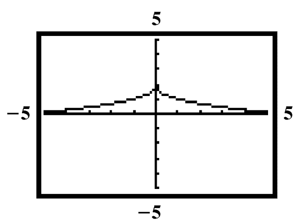
111.



Increasing: $(0, \infty)$

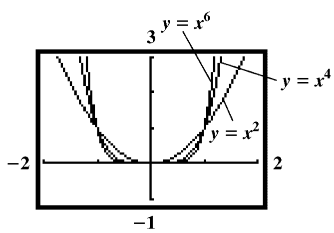
Decreasing: $(-\infty, 0)$

112.

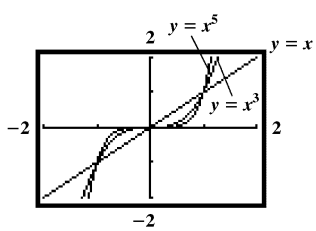


Increasing: $(-\infty, 0)$
Decreasing: $(0, \infty)$

113. a.



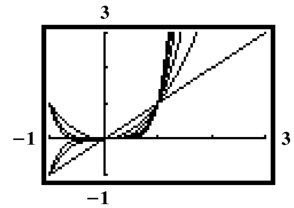
b.



c. Increasing: $(0, \infty)$
Decreasing: $(-\infty, 0)$

d. $f(x) = x^n$ is increasing from $(-\infty, \infty)$ when n is odd.

e.



114. does not make sense; Explanations will vary. Sample explanation: It's possible the graph is not defined at *a*.

115. makes sense

116. makes sense

117. makes sense

118. answers will vary

119. answers will vary

120. a. *h* is even if both *f* and *g* are even or if both *f* and *g* are odd.
f and *g* are both even:

$$h(-x) = \frac{f(-x)}{g(-x)} = \frac{f(x)}{g(x)} = h(x)$$

f and *g* are both odd:

$$h(-x) = \frac{f(-x)}{g(-x)} = \frac{-f(x)}{-g(x)} = \frac{f(x)}{g(x)} = h(x)$$

b. *h* is odd if *f* is odd and *g* is even or if *f* is even and *g* is odd.
f is odd and *g* is even:

$$h(-x) = \frac{f(-x)}{g(-x)} = \frac{-f(x)}{g(x)} = -\frac{f(x)}{g(x)} = -h(x)$$

f is even and *g* is odd:

$$h(-x) = \frac{f(-x)}{g(-x)} = \frac{f(x)}{-g(x)} = -\frac{f(x)}{g(x)} = -h(x)$$

121. answers will vary

122. $\dfrac{y_2 - y_1}{x_2 - x_1} = \dfrac{4-1}{-2-(-3)} = \dfrac{3}{1} = 3$

123. When $y = 0$:

$$\begin{aligned} 4x - 3y - 6 &= 0 \\ 4x - 3(0) - 6 &= 0 \\ 4x - 6 &= 0 \\ 4x &= 6 \\ x &= \frac{3}{2} \end{aligned}$$

The point is $\left(\frac{3}{2}, 0\right)$.

When $x = 0$:

$$\begin{aligned} 4x - 3y - 6 &= 0 \\ 4(0) - 3y - 6 &= 0 \\ -3y - 6 &= 0 \\ -3y &= 6 \\ x &= -2 \end{aligned}$$

The point is $(0, -2)$.

124.
$$\begin{aligned} 3x + 2y - 4 &= 0 \\ 2y &= -3x + 4 \\ y &= \frac{-3x + 4}{2} \end{aligned}$$
or
$$y = -\frac{3}{2}x + 2$$

Section 2.3

Check Point Exercises

1. **a.** $m = \dfrac{-2 - 4}{-4 - (-3)} = \dfrac{-6}{-1} = 6$

b. $m = \dfrac{5 - (-2)}{-1 - 4} = \dfrac{7}{-5} = -\dfrac{7}{5}$

2. Point-slope form:

$$\begin{aligned} y - y_1 &= m(x - x_1) \\ y - (-5) &= 6(x - 2) \\ y + 5 &= 6(x - 2) \end{aligned}$$

Slope-intercept form:

$$\begin{aligned} y + 5 &= 6(x - 2) \\ y + 5 &= 6x - 12 \\ y &= 6x - 17 \end{aligned}$$

3. $m = \dfrac{-6 - (-1)}{-1 - (-2)} = \dfrac{-5}{1} = -5$,

so the slope is –5.
Using the point (–2, –1), we get the following point-slope equation:

$$\begin{aligned} y - y_1 &= m(x - x_1) \\ y - (-1) &= -5[x - (-2)] \\ y + 1 &= -5(x + 2) \end{aligned}$$

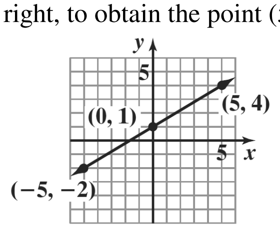
Using the point (–1, –6), we get the following point-slope equation:

$$\begin{aligned} y - y_1 &= m(x - x_1) \\ y - (-6) &= -5[x - (-1)] \\ y + 6 &= -5(x + 1) \end{aligned}$$

Solve the equation for *y*:

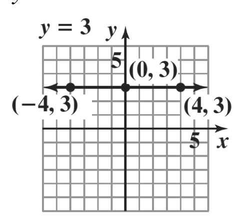
$$\begin{aligned} y + 1 &= -5(x + 2) \\ y + 1 &= -5x - 10 \\ y &= -5x - 11. \end{aligned}$$

4. The slope *m* is $\frac{3}{5}$ and the *y*-intercept is 1, so one point on the line is (1, 0). We can find a second point on the line by using the slope $m = \frac{3}{5} = \frac{\text{Rise}}{\text{Run}}$: starting at the point (0, 1), move 3 units up and 5 units to the right, to obtain the point (5, 4).

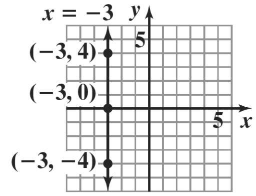


$f(x) = \frac{3}{5}x + 1$

5. $y = 3$ is a horizontal line.

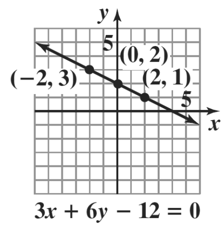


6. All ordered pairs that are solutions of $x = -3$ have a value of *x* that is always –3. Any value can be used for *y*.



7. $3x+6y-12=0$

$$6y=-3x+12$$
$$y=\frac{-3}{6}x+\frac{12}{6}$$
$$y=-\frac{1}{2}x+2$$



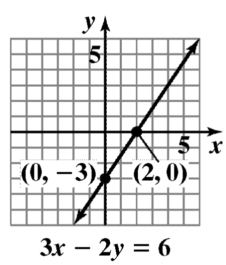
The slope is $-\frac{1}{2}$ and the y-intercept is 2.

8. Find the x-intercept:

$$3x-2y-6=0$$
$$3x-2(0)-6=0$$
$$3x-6=0$$
$$3x=6$$
$$x=2$$

Find the y-intercept:

$$3x-2y-6=0$$
$$3(0)-2y-6=0$$
$$-2y-6=0$$
$$-2y=6$$
$$y=-3$$



9. First find the slope**.**

$$m=\frac{\text{Change in } y}{\text{Change in } x}=\frac{57.64-57.04}{354-317}=\frac{0.6}{37}\approx 0.016$$

Use the point-slope form and then find slope-intercept form.

$$y-y_1=m(x-x_1)$$
$$y-57.04=0.016(x-317)$$
$$y-57.04=0.016x-5.072$$
$$y=0.016x+51.968$$
$$f(x)=0.016x+52.0$$

Find the temperature at a concentration of 600 parts per million.

$$f(x)=0.016x+52.0$$
$$f(600)=0.016(600)+52.0$$
$$=61.6$$

The temperature at a concentration of 600 parts per million would be 61.6°F.

Concept and Vocabulary Check 2.3

1. scatter plot; regression

2. $\frac{y_2-y_1}{x_2-x_1}$

3. positive

4. negative

5. zero

6. undefined

7. $y-y_1=m(x-x_1)$

8. $y=mx+b$; slope; y-intercept

9. $(0,3)$; 2; 5

10. horizontal

11. vertical

12. general

Exercise Set 2.3

1. $m=\frac{10-7}{8-4}=\frac{3}{4}$; rises

2. $m=\frac{4-1}{3-2}=\frac{3}{1}=3$; rises

3. $m=\frac{2-1}{2-(-2)}=\frac{1}{4}$; rises

4. $m=\frac{4-3}{2-(-1)}=\frac{1}{3}$; rises

5. $m=\frac{2-(-2)}{3-4}=\frac{0}{-1}=0$; horizontal

6. $m = \frac{-1-(-1)}{3-4} = \frac{0}{-1} = 0$; horizontal

7. $m = \frac{-1-4}{-1-(-2)} = \frac{-5}{1} = -5$; falls

8. $m = \frac{-2-(-4)}{4-6} = \frac{2}{-2} = -1$; falls

9. $m = \frac{-2-3}{5-5} = \frac{-5}{0}$ undefined; vertical

10. $m = \frac{5-(-4)}{3-3} = \frac{9}{0}$ undefined; vertical

11. $m = 2,\ x_1 = 3,\ y_1 = 5;$
point-slope form: $y - 5 = 2(x - 3)$;
slope-intercept form: $y - 5 = 2x - 6$
$y = 2x - 1$

12. point-slope form: $y - 3 = 4(x - 1)$;
$m = 4, x_1 = 1, y_1 = 3;$
slope-intercept form: $y = 4x - 1$

13. $m = 6,\ x_1 = -2,\ y_1 = 5;$
point-slope form: $y - 5 = 6(x + 2)$;
slope-intercept form: $y - 5 = 6x + 12$
$y = 6x + 17$

14. point-slope form: $y + 1 = 8(x - 4)$;
$m = 8, x_1 = 4, y_1 = -1;$
slope-intercept form: $y = 8x - 33$

15. $m = -3,\ x_1 = -2,\ y_1 = -3;$
point-slope form: $y + 3 = -3(x + 2)$;
slope-intercept form: $y + 3 = -3x - 6$
$y = -3x - 9$

16. point-slope form: $y + 2 = -5(x + 4)$;
$m = -5, x_1 = -4, y_1 = -2;$
slope-intercept form: $y = -5x - 22$

17. $m = -4,\ x_1 = -4,\ y_1 = 0;$
point-slope form: $y - 0 = -4(x + 4)$;
slope-intercept form: $y = -4(x + 4)$
$y = -4x - 16$

18. point-slope form: $y + 3 = -2(x - 0)$
$m = -2, x_1 = 0, y_1 = -3;$
slope-intercept form: $y = -2x - 3$

19. $m = -1,\ x_1 = \frac{-1}{2},\ y_1 = -2;$
point-slope form: $y + 2 = -1\left(x + \frac{1}{2}\right);$
slope-intercept form: $y + 2 = -x - \frac{1}{2}$
$y = -x - \frac{5}{2}$

20. point-slope form: $y + \frac{1}{4} = -1(x + 4);$
$m = -1, x_1 = -4, y_1 = -\frac{1}{4};$
slope-intercept form: $y = -x - \frac{17}{4}$

21. $m = \frac{1}{2},\ x_1 = 0,\ y_1 = 0;$
point-slope form: $y - 0 = \frac{1}{2}(x - 0);$
slope-intercept form: $y = \frac{1}{2}x$

22. point-slope form: $y - 0 = \frac{1}{3}(x - 0);$
$m = \frac{1}{3}, x_1 = 0, y_1 = 0;$
slope-intercept form: $y = \frac{1}{3}x$

23. $m = -\frac{2}{3},\ x_1 = 6,\ y_1 = -2;$
point-slope form: $y + 2 = -\frac{2}{3}(x - 6);$
slope-intercept form: $y + 2 = -\frac{2}{3}x + 4$
$y = -\frac{2}{3}x + 2$

24. point-slope form: $y + 4 = -\frac{3}{5}(x - 10);$
$m = -\frac{3}{5}, x_1 = 10, y_1 = -4;$
slope-intercept form: $y = -\frac{3}{5}x + 2$

25. $m = \frac{10-2}{5-1} = \frac{8}{4} = 2$;
point-slope form: $y - 2 = 2(x - 1)$ using $(x_1, y_1) = (1, 2)$, or $y - 10 = 2(x - 5)$ using $(x_1, y_1) = (5, 10)$;
slope-intercept form: $y - 2 = 2x - 2$ or
$y - 10 = 2x - 10$,
$y = 2x$

26. $m = \frac{15-5}{8-3} = \frac{10}{5} = 2$;
point-slope form: $y - 5 = 2(x - 3)$ using $(x_1, y_1) = (3,5)$, or $y - 15 = 2(x - 8)$ using $(x_1, y_1) = (8,15)$;
slope-intercept form: $y = 2x - 1$

27. $m = \frac{3-0}{0-(-3)} = \frac{3}{3} = 1$;
point-slope form: $y - 0 = 1(x + 3)$ using $(x_1, y_1) = (-3, 0)$, or $y - 3 = 1(x - 0)$ using $(x_1, y_1) = (0, 3)$; slope-intercept form: $y = x + 3$

28. $m = \frac{2-0}{0-(-2)} = \frac{2}{2} = 1$;
point-slope form: $y - 0 = 1(x + 2)$ using $(x_1, y_1) = (-2,0)$, or $y - 2 = 1(x - 0)$ using $(x_1, y_1) = (0,2)$;
slope-intercept form: $y = x + 2$

29. $m = \frac{4-(-1)}{2-(-3)} = \frac{5}{5} = 1$;
point-slope form: $y + 1 = 1(x + 3)$ using $(x_1, y_1) = (-3, -1)$, or $y - 4 = 1(x - 2)$ using $(x_1, y_1) = (2, 4)$; slope-intercept form:
$y + 1 = x + 3$ or
$y - 4 = x - 2$
$y = x + 2$

30. $m = \frac{-1-(-4)}{1-(-2)} = \frac{3}{3} = 1$;
point-slope form: $y + 4 = 1(x + 2)$ using $(x_1, y_1) = (-2,-4)$, or $y + 1 = 1(x - 1)$ using $(x_1, y_1) = (1,-1)$
slope-intercept form: $y = x - 2$

31. $m = \frac{6-(-2)}{3-(-3)} = \frac{8}{6} = \frac{4}{3}$;
point-slope form: $y + 2 = \frac{4}{3}(x + 3)$ using $(x_1, y_1) = (-3, -2)$, or $y - 6 = \frac{4}{3}(x - 3)$ using $(x_1, y_1) = (3, 6)$;
slope-intercept form: $y + 2 = \frac{4}{3x} + 4$ or
$y - 6 = \frac{4}{3}x - 4$,
$y = \frac{4}{3}x + 2$

32. $m = \frac{-2-6}{3-(-3)} = \frac{-8}{6} = -\frac{4}{3}$;
point-slope form: $y - 6 = -\frac{4}{3}(x + 3)$ using $(x_1, y_1) = (-3,6)$, or $y + 2 = -\frac{4}{3}(x - 3)$ using $(x_1, y_1) = (3,-2)$;
slope-intercept form: $y = -\frac{4}{3}x + 2$

33. $m = \frac{-1-(-1)}{4-(-3)} = \frac{0}{7} = 0$;
point-slope form: $y + 1 = 0(x + 3)$ using $(x_1, y_1) = (-3, -1)$, or $y + 1 = 0(x - 4)$ using $(x_1, y_1) = (4, -1)$;
slope-intercept form: $y + 1 = 0$, so
$y = -1$

34. $m = \frac{-5-(-5)}{6-(-2)} = \frac{0}{8} = 0$;
point-slope form: $y + 5 = 0(x + 2)$ using $(x_1, y_1) = (-2,-5)$, or $y + 5 = 0(x - 6)$ using $(x_1, y_1) = (6,-5)$;
slope-intercept form: $y + 5 = 0$, so
$y = -5$

35. $m = \frac{0-4}{-2-2} = \frac{-4}{-4} = 1$;
point-slope form: $y - 4 = 1(x - 2)$ using $(x_1, y_1) = (2, 4)$, or $y - 0 = 1(x + 2)$ using $(x_1, y_1) = (-2, 0)$;
slope-intercept form: $y - 9 = x - 2$, or
$y = x + 2$

36. $m=\dfrac{0-(-3)}{-1-1}=\dfrac{3}{-2}=-\dfrac{3}{2}$

point-slope form: $y+3=-\dfrac{3}{2}(x-1)$ using $(x_1,y_1)=(1,-3)$, or $y-0=-\dfrac{3}{2}(x+1)$ using $(x_1,y_1)=(-1,0)$;

slope-intercept form: $y+3=-\dfrac{3}{2}x+\dfrac{3}{2}$, or

$$y=-\frac{3}{2}x-\frac{3}{2}$$

37. $m=\dfrac{4-0}{0-\left(-\frac{1}{2}\right)}=\dfrac{4}{\frac{1}{2}}=8$;

point-slope form: $y-4=8(x-0)$ using $(x_1,\ y_1)=(0,\ 4)$, or $y-0=8\left(x+\frac{1}{2}\right)$ using $(x_1,\ y_1)=\left(-\frac{1}{2},\ 0\right)$; or $y-0=8\left(x+\frac{1}{2}\right)$

slope-intercept form: $y=8x+4$

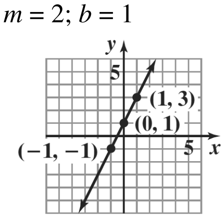
38. $m=\dfrac{-2-0}{0-4}=\dfrac{-2}{-4}=\dfrac{1}{2}$;

point-slope form: $y-0=\dfrac{1}{2}(x-4)$ using $(x_1,y_1)=(4,0)$,

or $y+2=\dfrac{1}{2}(x-0)$ using $(x_1,y_1)=(0,-2)$;

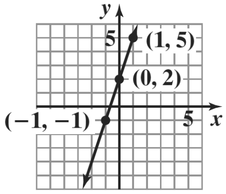
slope-intercept form: $y=\dfrac{1}{2}x-2$

39. $m=2$; $b=1$



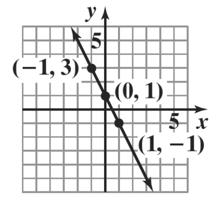
$y = 2x + 1$

40. $m=3$; $b=2$



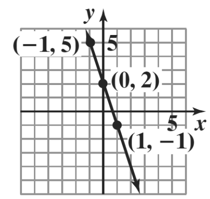
$y = 3x + 2$

41. $m=-2$; $b=1$



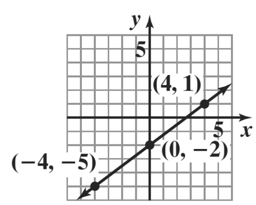
$f(x) = -2x + 1$

42. $m=-3$; $b=2$



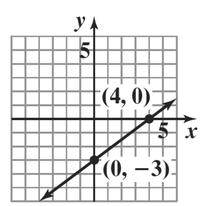
$f(x) = -3x + 2$

43. $m=\dfrac{3}{4}$; $b=-2$



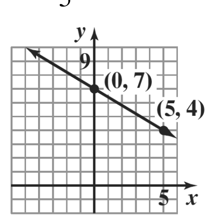
$f(x) = \dfrac{3}{4}x - 2$

44. $m=\dfrac{3}{4}$; $b=-3$



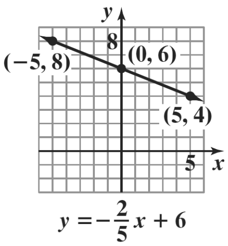
$f(x) = \dfrac{3}{4}x - 3$

45. $m=-\dfrac{3}{5}$; $b=7$

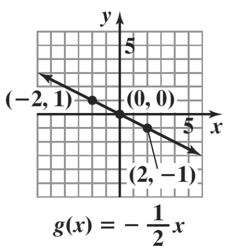


$y = -\dfrac{3}{5}x + 7$

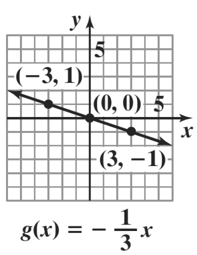
46. $m = -\frac{2}{5}$; $b = 6$



47. $m = -\frac{1}{2}$; $b = 0$



48. $m = -\frac{1}{3}$; $b = 0$



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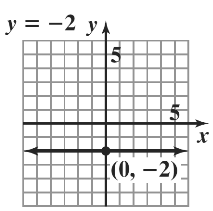

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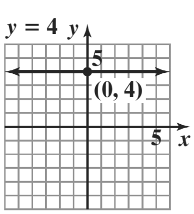

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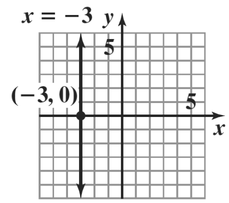

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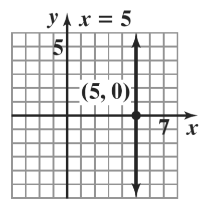

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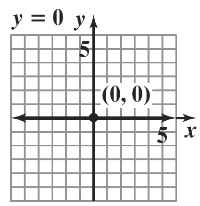

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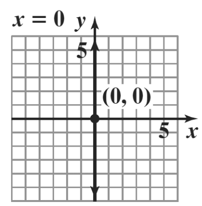

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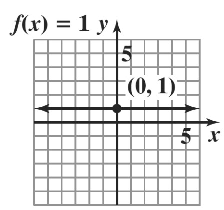

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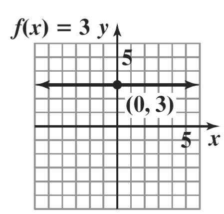
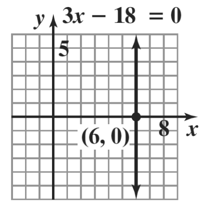


57. $3x - 18 = 0$

$3x = 18$

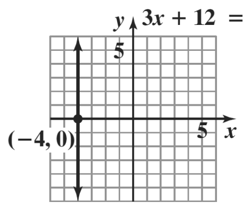
$x = 6$



58. $3x + 12 = 0$

$3x = -12$

$x = -4$



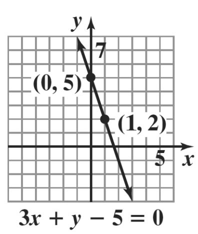
59. **a.** $3x + y - 5 = 0$

$y - 5 = -3x$

$y = -3x + 5$

b. $m = -3$; $b = 5$

c.



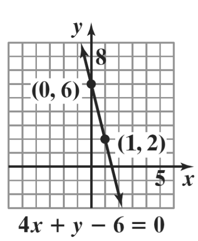
60. **a.** $4x + y - 6 = 0$

$y - 6 = -4x$

$y = -4x + 6$

b. $m = -4; b = 6$

c.



61. **a.** $2x + 3y - 18 = 0$

$2x - 18 = -3y$

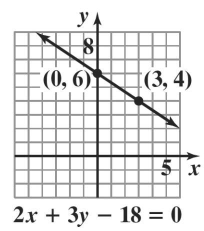
$-3y = 2x - 18$

$$y = \frac{2}{-3}x - \frac{18}{-3}$$

$$y = -\frac{2}{3}x + 6$$

b. $m = -\frac{2}{3};\ b = 6$

c.



62. **a.** $4x + 6y + 12 = 0$

$4x + 12 = -6y$

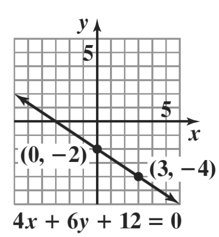
$-6y = 4x + 12$

$$y = \frac{4}{-6}x + \frac{12}{-6}$$

$$y = -\frac{2}{3}x - 2$$

b. $m = -\frac{2}{3};\ b = -2$

c.



63. **a.** $8x - 4y - 12 = 0$

$8x - 12 = 4y$

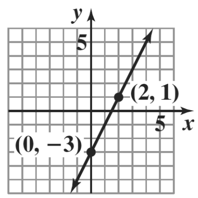
$4y = 8x - 12$

$$y = \frac{8}{4}x - \frac{12}{4}$$

$y = 2x - 3$

b. $m = 2$; $b = -3$

c.

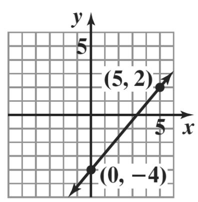


$8x - 4y - 12 = 0$

64. **a.**
$$6x - 5y - 20 = 0$$
$$6x - 20 = 5y$$
$$5y = 6x - 20$$
$$y = \frac{6}{5}x - \frac{20}{5}$$
$$y = \frac{6}{5}x - 4$$

b. $m = \frac{6}{5}; b = -4$

c.

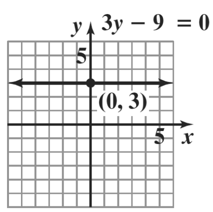


$6x - 5y - 20 = 0$

65. **a.**
$$3y - 9 = 0$$
$$3y = 9$$
$$y = 3$$

b. $m = 0;\ b = 3$

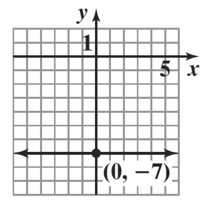
c.



66. **a.**
$$4y + 28 = 0$$
$$4y = -28$$
$$y = -7$$

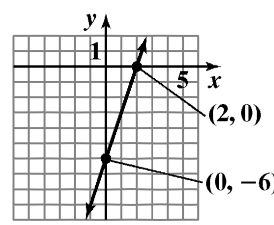
b. $m = 0;\ b = -7$

c.



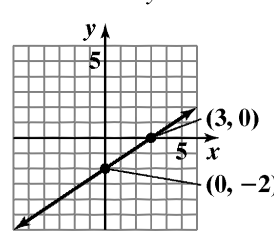
$4y + 28 = 0$

67. Find the x-intercept:
$$6x - 2y - 12 = 0$$
$$6x - 2(0) - 12 = 0$$
$$6x - 12 = 0$$
$$6x = 12$$
$$x = 2$$
Find the y-intercept:
$$6x - 2y - 12 = 0$$
$$6(0) - 2y - 12 = 0$$
$$-2y - 12 = 0$$
$$-2y = 12$$
$$y = -6$$



$6x - 2y - 12 = 0$

68. Find the x-intercept:
$$6x - 9y - 18 = 0$$
$$6x - 9(0) - 18 = 0$$
$$6x - 18 = 0$$
$$6x = 18$$
$$x = 3$$
Find the y-intercept:
$$6x - 9y - 18 = 0$$
$$6(0) - 9y - 18 = 0$$
$$-9y - 18 = 0$$
$$-9y = 18$$
$$y = -2$$



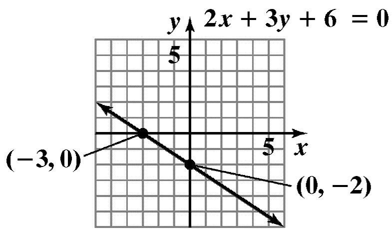
$6x - 9y - 18 = 0$

69. Find the x-intercept:

$$\begin{aligned} 2x+3y+6&=0\\ 2x+3(0)+6&=0\\ 2x+6&=0\\ 2x&=-6\\ x&=-3 \end{aligned}$$

Find the y-intercept:

$$\begin{aligned} 2x+3y+6&=0\\ 2(0)+3y+6&=0\\ 3y+6&=0\\ 3y&=-6\\ y&=-2 \end{aligned}$$

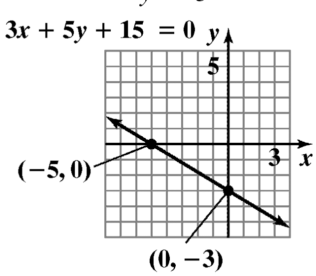


70. Find the x-intercept:

$$\begin{aligned} 3x+5y+15&=0\\ 3x+5(0)+15&=0\\ 3x+15&=0\\ 3x&=-15\\ x&=-5 \end{aligned}$$

Find the y-intercept:

$$\begin{aligned} 3x+5y+15&=0\\ 3(0)+5y+15&=0\\ 5y+15&=0\\ 5y&=-15\\ y&=-3 \end{aligned}$$

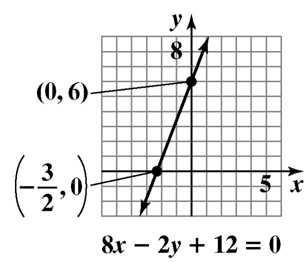


71. Find the x-intercept:

$$\begin{aligned} 8x-2y+12&=0\\ 8x-2(0)+12&=0\\ 8x+12&=0\\ 8x&=-12\\ \frac{8x}{8}&=\frac{-12}{8}\\ x&=\frac{-3}{2} \end{aligned}$$

Find the y-intercept:

$$\begin{aligned} 8x-2y+12&=0\\ 8(0)-2y+12&=0\\ -2y+12&=0\\ -2y&=-12\\ y&=-6 \end{aligned}$$

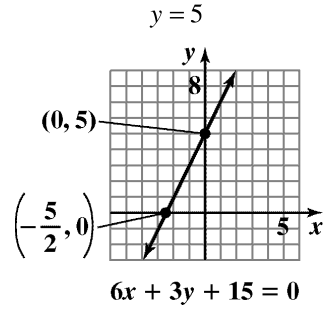


72. Find the x-intercept:

$$\begin{aligned} 6x-3y+15&=0\\ 6x-3(0)+15&=0\\ 6x+15&=0\\ 6x&=-15\\ \frac{6x}{6}&=\frac{-15}{6}\\ x&=-\frac{5}{2} \end{aligned}$$

Find the y-intercept:

$$\begin{aligned} 6x-3y+15&=0\\ 6(0)-3y+15&=0\\ -3y+15&=0\\ -3y&=-15\\ y&=5 \end{aligned}$$



73. $m = \frac{0-a}{b-0} = \frac{-a}{b} = -\frac{a}{b}$

Since a and b are both positive, $-\frac{a}{b}$ is negative. Therefore, the line falls.

74. $m = \frac{-b-0}{0-(-a)} = \frac{-b}{a} = -\frac{b}{a}$

Since a and b are both positive, $-\frac{b}{a}$ is negative. Therefore, the line falls.

75. $m = \frac{(b+c)-b}{a-a} = \frac{c}{0}$

The slope is undefined.
The line is vertical.

76. $m = \frac{(a+c)-c}{a-(a-b)} = \frac{a}{b}$

Since a and b are both positive, $\frac{a}{b}$ is positive. Therefore, the line rises.

77. $Ax + By = C$

$By = -Ax + C$

$y = -\frac{A}{B}x + \frac{C}{B}$

The slope is $-\frac{A}{B}$ and the $y-$intercept is $\frac{C}{B}$.

78. $Ax = By - C$

$Ax + C = By$

$\frac{A}{B}x + \frac{C}{B} = y$

The slope is $\frac{A}{B}$ and the $y-$intercept is $\frac{C}{B}$.

79. $-3 = \frac{4-y}{1-3}$

$-3 = \frac{4-y}{-2}$

$6 = 4 - y$

$2 = -y$

$-2 = y$

80. $\frac{1}{3} = \frac{-4-y}{4-(-2)}$

$\frac{1}{3} = \frac{-4-y}{4+2}$

$\frac{1}{3} = \frac{-4-y}{6}$

$6 = 3(-4-y)$

$6 = -12 - 3y$

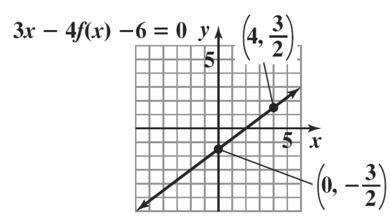
$18 = -3y$

$-6 = y$

81. $3x - 4f(x) = 6$

$-4f(x) = -3x + 6$

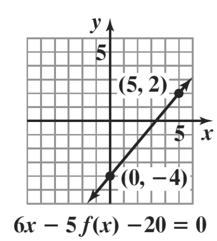
$f(x) = \frac{3}{4}x - \frac{3}{2}$



82. $6x - 5f(x) = 20$

$-5f(x) = -6x + 20$

$f(x) = \frac{6}{5}x - 4$



83. Using the slope-intercept form for the equation of a line:

$-1 = -2(3) + b$

$-1 = -6 + b$

$5 = b$

84. $-6 = -\frac{3}{2}(2) + b$

$-6 = -3 + b$

$-3 = b$

85. m_1, m_3, m_2, m_4

86. b_2, b_1, b_4, b_3

87. a. First, find the slope using $(20, 38.9)$ and $(10, 31.1)$.

$$m = \frac{38.9 - 31.1}{20 - 10} = \frac{7.8}{10} = 0.78$$

Then use the slope and one of the points to write the equation in point-slope form.

$$y - y_1 = m(x - x_1)$$
$$y - 31.1 = 0.78(x - 10)$$
or
$$y - 38.9 = 0.78(x - 20)$$

b. $$y - 31.1 = 0.78(x - 10)$$
$$y - 31.1 = 0.78x - 7.8$$
$$y = 0.78x + 23.3$$
$$f(x) = 0.78x + 23.3$$

c. $f(40) = 0.78(40) + 23.3 = 54.5$

The linear function predicts the percentage of never married American females, ages 25 – 29, to be 54.5% in 2020.

88. a. First, find the slope using $(20, 51.7)$ and $(10, 45.2)$.

$$m = \frac{51.7 - 45.2}{20 - 10} = \frac{6.5}{10} = 0.65$$

Then use the slope and one of the points to write the equation in point-slope form.

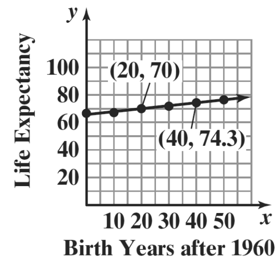
$$y - y_1 = m(x - x_1)$$
$$y - 45.2 = 0.65(x - 10)$$
or
$$y - 51.7 = 0.65(x - 20)$$

b. $$y - 45.2 = 0.65(x - 10)$$
$$y - 45.2 = 0.65x - 6.5$$
$$y = 0.65x + 38.7$$
$$f(x) = 0.65x + 38.7$$

c. $f(35) = 0.65(35) + 38.7 = 61.45$

The linear function predicts the percentage of never married American males, ages 25 – 29, to be 61.45% in 2015.

89. a. **Life Expectancy for United States Males, by Year of Birth**

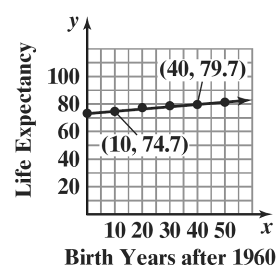


b. $$m = \frac{\text{Change in } y}{\text{Change in } x} = \frac{74.3 - 70.0}{40 - 20} = 0.215$$
$$y - y_1 = m(x - x_1)$$
$$y - 70.0 = 0.215(x - 20)$$
$$y - 70.0 = 0.215x - 4.3$$
$$y = 0.215x + 65.7$$
$$E(x) = 0.215x + 65.7$$

c. $$E(x) = 0.215x + 65.7$$
$$E(60) = 0.215(60) + 65.7$$
$$= 78.6$$

The life expectancy of American men born in 2020 is expected to be 78.6.

90. a. **Life Expectancy for United States Females, by Year of Birth**



b. $$m = \frac{\text{Change in } y}{\text{Change in } x} = \frac{79.7 - 74.7}{40 - 10} \approx 0.17$$
$$y - y_1 = m(x - x_1)$$
$$y - 74.7 = 0.17(x - 10)$$
$$y - 74.7 = 0.17x - 1.7$$
$$y = 0.17x + 73$$
$$E(x) = 0.17x + 73$$

c. $$E(x) = 0.17x + 73$$
$$E(60) = 0.17(60) + 73$$
$$= 83.2$$

The life expectancy of American women born in 2020 is expected to be 83.2.

91. (10, 230) (60, 110) Points may vary.

$$m = \frac{110-230}{60-10} = -\frac{120}{50} = -2.4$$

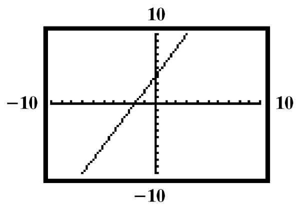
$$y - 230 = -2.4(x-10)$$
$$y - 230 = -2.4x + 24$$
$$y = -2.4x + 254$$

Answers will vary for predictions.

92. – 99. Answers will vary.

100. Two points are (0,4) and (10,24).

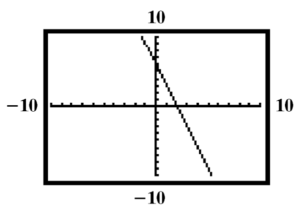
$$m = \frac{24-4}{10-0} = \frac{20}{10} = 2.$$



101. Two points are (0, 6) and (10, –24).

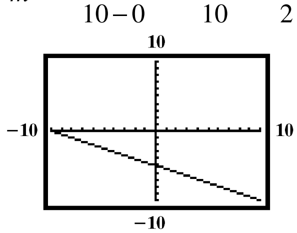
$$m = \frac{-24-6}{10-0} = \frac{-30}{10} = -3.$$

Check: $y = mx + b$: $y = -3x + 6$.



102. Two points are (0,–5) and (10,–10).

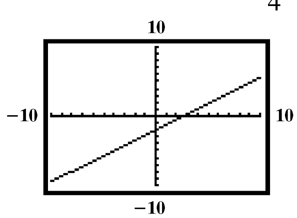
$$m = \frac{-10-(-5)}{10-0} = \frac{-5}{10} = -\frac{1}{2}.$$



103. Two points are (0, –2) and (10, 5.5).

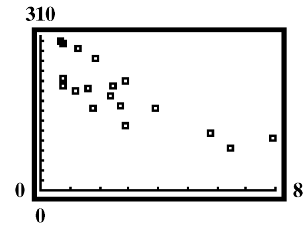
$$m = \frac{5.5-(-2)}{10-0} = \frac{7.5}{10} = 0.75 \text{ or } \frac{3}{4}.$$

Check: $y = mx + b$: $y = \frac{3}{4}x - 2$.



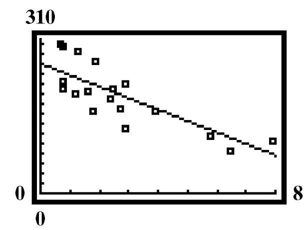
104. a. Enter data from table.

b.



c. $a = -22.96876741$
$b = 260.5633751$
$r = -0.8428126855$

d.



105. does not make sense; Explanations will vary. Sample explanation: Linear functions never change from increasing to decreasing.

106. does not make sense; Explanations will vary. Sample explanation: Since college cost are going up, this function has a positive slope.

107. does not make sense; Explanations will vary. Sample explanation: The slope of line's whose equations are in this form can be determined in several ways. One such way is to rewrite the equation in slope-intercept form.

108. makes sense

109. false; Changes to make the statement true will vary. A sample change is: It is possible for *m* to equal *b*.

110. false; Changes to make the statement true will vary. A sample change is: Slope-intercept form is $y = mx + b$. Vertical lines have equations of the form $x = a$. Equations of this form have undefined slope and cannot be written in slope-intercept form.

111. true

112. false; Changes to make the statement true will vary. A sample change is: The graph of $x = 7$ is a vertical line through the point (7, 0).

113. We are given that the $x-$intercept is -2 and the $y-$intercept is 4. We can use the points $(-2,0)$ and $(0,4)$ to find the slope.

$m=\frac{4-0}{0-(-2)}=\frac{4}{0+2}=\frac{4}{2}=2$

Using the slope and one of the intercepts, we can write the line in point-slope form.

$$y-y_1=m(x-x_1)$$
$$y-0=2(x-(-2))$$
$$y=2(x+2)$$
$$y=2x+4$$
$$-2x+y=4$$

Find the x– and y–coefficients for the equation of the line with right-hand-side equal to 12. Multiply both sides of $-2x+y=4$ by 3 to obtain 12 on the right-hand-side.

$$-2x+y=4$$
$$3(-2x+y)=3(4)$$
$$-6x+3y=12$$

Therefore, the coefficient of x is –6 and the coefficient of y is 3.

114. We are given that the $y-$intercept is -6 and the slope is $\frac{1}{2}$.

So the equation of the line is $y=\frac{1}{2}x-6$.

We can put this equation in the form $ax+by=c$ to find the missing coefficients.

$$y=\frac{1}{2}x-6$$
$$y-\frac{1}{2}x=-6$$
$$2\left(y-\frac{1}{2}x\right)=2(-6)$$
$$2y-x=-12$$
$$x-2y=12$$

Therefore, the coefficient of x is 1 and the coefficient of y is –2.

115. Answers will vary.

116. Let (25, 40) and (125, 280) be ordered pairs (M, E) where M is degrees Madonna and E is degrees Elvis. Then $m=\frac{280-40}{125-25}=\frac{240}{100}=2.4$. Using $(x_1,y_1)=(25,40)$, point-slope form tells us that
$E-40=2.4(M-25)$ or
$E=2.4M-20$.

117. Answers will vary.

118. Since the slope is the same as the slope of $y=2x+1$, then $m=2$.

$$y-y_1=m(x-x_1)$$
$$y-1=2(x-(-3))$$
$$y-1=2(x+3)$$
$$y-1=2x+6$$
$$y=2x+7$$

119. Since the slope is the negative reciprocal of $-\frac{1}{4}$, then $m=4$.

$$y-y_1=m(x-x_1)$$
$$y-(-5)=4(x-3)$$
$$y+5=4x-12$$
$$-4x+y+17=0$$
$$4x-y-17=0$$

120.
$$\frac{f(x_2)-f(x_1)}{x_2-x_1}=\frac{f(4)-f(1)}{4-1}=\frac{4^2-1^2}{4-1}=\frac{15}{3}=5$$

Section 2.4

Check Point Exercises

1. The slope of the line $y = 3x + 1$ is 3.

$$\begin{aligned} y - y_1 &= m(x - x_1) \\ y - 5 &= 3\big(x - (-2)\big) \\ y - 5 &= 3(x + 2) \quad \text{point-slope} \\ y - 5 &= 3x + 6 \\ y &= 3x + 11 \quad \text{slope-intercept} \end{aligned}$$

2. a. Write the equation in slope-intercept form:

$$\begin{aligned} x + 3y - 12 &= 0 \\ 3y &= -x + 12 \\ y &= -\frac{1}{3}x + 4 \end{aligned}$$

The slope of this line is $-\frac{1}{3}$ thus the slope of any line perpendicular to this line is 3.

b. Use $m = 3$ and the point (–2, –6) to write the equation.

$$\begin{aligned} y - y_1 &= m(x - x_1) \\ y - (-6) &= 3\big(x - (-2)\big) \\ y + 6 &= 3(x + 2) \\ y + 6 &= 3x + 6 \\ -3x + y &= 0 \\ 3x - y &= 0 \quad \text{general form} \end{aligned}$$

3. $m = \dfrac{\text{Change in } y}{\text{Change in } x} = \dfrac{14.7 - 9.0}{2008 - 1990} = \dfrac{5.7}{18} \approx 0.32$

The slope indicates that the number of U.S. men living alone increased at a rate of 0.32 million each year.
The rate of change is 0.32 million men per year.

4. a. $\dfrac{f(x_2) - f(x_1)}{x_2 - x_1} = \dfrac{1^3 - 0^3}{1 - 0} = 1$

b. $\dfrac{f(x_2) - f(x_1)}{x_2 - x_1} = \dfrac{2^3 - 1^3}{2 - 1} = \dfrac{8 - 1}{1} = 7$

c. $\dfrac{f(x_2) - f(x_1)}{x_2 - x_1} = \dfrac{0^3 - (-2)^3}{0 - (-2)} = \dfrac{8}{2} = 4$

5.
$$\begin{aligned} \frac{f(x_2) - f(x_1)}{x_2 - x_1} &= \frac{f(3) - f(1)}{3 - 1} \\ &= \frac{0.05 - 0.03}{3 - 1} \\ &= 0.01 \end{aligned}$$

The average rate of change in the drug's concentration between 1 hour and 3 hours is 0.01 mg per 100 mL per hour.

Concept and Vocabulary Check 2.4

1. the same

2. -1

3. $-\frac{1}{3}$; 3

4. -2 ; $\frac{1}{2}$

5. y; x

6. $\dfrac{f(x_2) - f(x_1)}{x_2 - x_1}$

Exercise Set 2.4

1. Since L is parallel to $y = 2x$, we know it will have slope $m = 2$. We are given that it passes through $(4, 2)$. We use the slope and point to write the equation in point-slope form.

$$\begin{aligned} y - y_1 &= m(x - x_1) \\ y - 2 &= 2(x - 4) \end{aligned}$$

Solve for y to obtain slope-intercept form.

$$\begin{aligned} y - 2 &= 2(x - 4) \\ y - 2 &= 2x - 8 \\ y &= 2x - 6 \end{aligned}$$

In function notation, the equation of the line is $f(x) = 2x - 6$.

2. L will have slope $m=-2$. Using the point and the slope, we have $y-4=-2(x-3)$. Solve for y to obtain slope-intercept form.

$$y-4=-2x+6$$
$$y=-2x+10$$
$$f(x)=-2x+10$$

3. Since L is perpendicular to $y=2x$, we know it will have slope $m=-\frac{1}{2}$. We are given that it passes through $(2,4)$. We use the slope and point to write the equation in point-slope form.

$$y-y_1=m(x-x_1)$$
$$y-4=-\frac{1}{2}(x-2)$$

Solve for y to obtain slope-intercept form.

$$y-4=-\frac{1}{2}(x-2)$$
$$y-4=-\frac{1}{2}x+1$$
$$y=-\frac{1}{2}x+5$$

In function notation, the equation of the line is

$$f(x)=-\frac{1}{2}x+5.$$

4. L will have slope $m=\frac{1}{2}$. The line passes through (–1, 2). Use the slope and point to write the equation in point-slope form.

$$y-2=\frac{1}{2}(x-(-1))$$
$$y-2=\frac{1}{2}(x+1)$$

Solve for y to obtain slope-intercept form.

$$y-2=\frac{1}{2}x+\frac{1}{2}$$
$$y=\frac{1}{2}x+\frac{1}{2}+2$$
$$y=\frac{1}{2}x+\frac{5}{2}$$
$$f(x)=\frac{1}{2}x+\frac{5}{2}$$

5. $m=-4$ since the line is parallel to $y=-4x+3$; $x_1=-8$, $y_1=-10$;

point-slope form: $y+10=-4(x+8)$

slope-intercept form: $y+10=-4x-32$

$$y=-4x-42$$

6. $m=-5$ since the line is parallel to $y=-5x+4$; $x_1=-2, y_1=-7$;

point-slope form: $y+7=-5(x+2)$

slope-intercept form: $y+7=-5x-10$

$$y=-5x-17$$

7. $m=-5$ since the line is perpendicular to $y=\frac{1}{5}x+6$; $x_1=2$, $y_1=-3$;

point-slope form: $y+3=-5(x-2)$

slope-intercept form: $y+3=-5x+10$

$$y=-5x+7$$

8. $m=-3$ since the line is perpendicular to $y=\frac{1}{3}x+7$; $x_1=-4, y_1=2$;

point-slope form: $y-2=-3(x+4)$

slope-intercept form: $y-2=-3x-12$

$$y=-3x-10$$

9.

$$2x-3y-7=0$$
$$-3y=-2x+7$$
$$y=\frac{2}{3}x-\frac{7}{3}$$

The slope of the given line is $\frac{2}{3}$, so $m=\frac{2}{3}$ since the lines are parallel.

point-slope form: $y-2=\frac{2}{3}(x+2)$

general form: $2x-3y+10=0$

10.

$$3x-2y-=0$$
$$-2y=-3x+5$$
$$y=\frac{3}{2}x-\frac{5}{2}$$

The slope of the given line is $\frac{3}{2}$, so $m=\frac{3}{2}$ since the lines are parallel.

point-slope form: $y-3=\frac{3}{2}(x+1)$

general form: $3x-2y+9=0$

11. $x-2y-3=0$

$$-2y=-x+3$$

$$y=\frac{1}{2}x-\frac{3}{2}$$

The slope of the given line is $\frac{1}{2}$, so $m=-2$ since the lines are perpendicular.

point-slope form: $y+7=-2(x-4)$

general form: $2x+y-1=0$

12. $x+7y-12=0$

$$7y=-x+12$$

$$y=\frac{-1}{7}x+\frac{12}{7}$$

The slope of the given line is $-\frac{1}{7}$, so $m=7$ since the lines are perpendicular.

point-slope form: $y+9=7(x-5)$

general form: $7x-y-44=0$

13. $\frac{15-0}{5-0}=\frac{15}{5}=3$

14. $\frac{24-0}{4-0}=\frac{24}{4}=6$

15. $$\frac{5^2+2\cdot 5-(3^2+2\cdot 3)}{5-3}=\frac{25+10-(9+6)}{2}=\frac{20}{2}=10$$

16. $$\frac{6^2-2(6)-(3^2-2\cdot 3)}{6-3}=\frac{36-12-(9-6)}{3}=\frac{21}{3}=7$$

17. $\frac{\sqrt{9}-\sqrt{4}}{9-4}=\frac{3-2}{5}=\frac{1}{5}$

18. $\frac{\sqrt{16}-\sqrt{9}}{16-9}=\frac{4-3}{7}=\frac{1}{7}$

19. Since the line is perpendicular to $x=6$ which is a vertical line, we know the graph of f is a horizontal line with 0 slope. The graph of f passes through $(-1,5)$, so the equation of f is $f(x)=5$.

20. Since the line is perpendicular to $x=-4$ which is a vertical line, we know the graph of f is a horizontal line with 0 slope. The graph of f passes through $(-2,6)$, so the equation of f is $f(x)=6$.

21. First we need to find the equation of the line with $x-$intercept of 2 and $y-$intercept of -4. This line will pass through $(2,0)$ and $(0,-4)$. We use these points to find the slope.

$$m=\frac{-4-0}{0-2}=\frac{-4}{-2}=2$$

Since the graph of f is perpendicular to this line, it will have slope $m=-\frac{1}{2}$.

Use the point $(-6,4)$ and the slope $-\frac{1}{2}$ to find the equation of the line.

$$y-y_1=m(x-x_1)$$

$$y-4=-\frac{1}{2}(x-(-6))$$

$$y-4=-\frac{1}{2}(x+6)$$

$$y-4=-\frac{1}{2}x-3$$

$$y=-\frac{1}{2}x+1$$

$$f(x)=-\frac{1}{2}x+1$$

22. First we need to find the equation of the line with $x-$intercept of 3 and $y-$intercept of -9. This line will pass through $(3,0)$ and $(0,-9)$. We use these points to find the slope.

$$m=\frac{-9-0}{0-3}=\frac{-9}{-3}=3$$

Since the graph of f is perpendicular to this line, it will have slope $m=-\frac{1}{3}$.

Use the point $(-5,6)$ and the slope $-\frac{1}{3}$ to find the equation of the line.

$$y-y_1=m(x-x_1)$$
$$y-6=-\frac{1}{3}(x-(-5))$$
$$y-6=-\frac{1}{3}(x+5)$$
$$y-6=-\frac{1}{3}x-\frac{5}{3}$$
$$y=-\frac{1}{3}x+\frac{13}{3}$$
$$f(x)=-\frac{1}{3}x+\frac{13}{3}$$

23. First put the equation $3x-2y-4=0$ in slope-intercept form.

$$3x-2y-4=0$$
$$-2y=-3x+4$$
$$y=\frac{3}{2}x-2$$

The equation of f will have slope $-\frac{2}{3}$ since it is perpendicular to the line above and the same $y-$intercept -2.

So the equation of f is $f(x)=-\frac{2}{3}x-2.$

24. First put the equation $4x-y-6=0$ in slope-intercept form.

$$4x-y-6=0$$
$$-y=-4x+6$$
$$y=4x-6$$

The equation of f will have slope $-\frac{1}{4}$ since it is perpendicular to the line above and the same $y-$intercept -6.

So the equation of f is $f(x)=-\frac{1}{4}x-6.$

25. $p(x)=-0.25x+22$

26. $p(x)=0.22x+3$

27. $m=\dfrac{1163-617}{1998-1994}=\dfrac{546}{4}\approx 137$

There was an average increase of approximately 137 discharges per year.

28. $m=\dfrac{623-1273}{2006-2001}=\dfrac{-650}{5}\approx -130$

There was an average decrease of approximately 130 discharges per year.

29. **a.** $f(x)=1.1x^3-35x^2+264x+557$

$$f(0)=1.1(0)^3-35(0)^2+264(0)+557=557$$
$$f(4)=1.1(4)^3-35(4)^2+264(4)+557=1123.4$$

$$m=\frac{1123.4-557}{4-0}\approx 142$$

b. This overestimates by 5 discharges per year.

30. **a.** $f(x)=1.1x^3-35x^2+264x+557$

$$f(0)=1.1(7)^3-35(7)^2+264(7)+557=1067.3$$
$$f(12)=1.1(12)^3-35(12)^2+264(12)+557=585.8$$

$$m=\frac{585.8-1067.3}{12-7}\approx -96$$

b. This underestimates the decrease by 34 discharges per year.

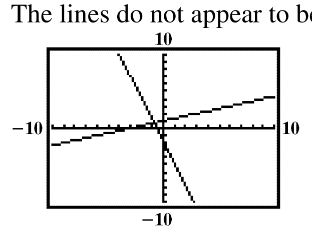
31. – 36. Answers will vary.

37. $y=\frac{1}{3}x+1$

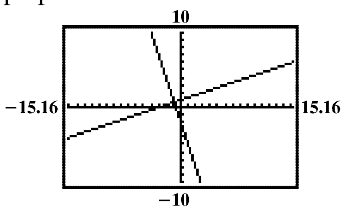
$y=-3x-2$

a. The lines are perpendicular because their slopes are negative reciprocals of each other. This is verified because product of their slopes is –1.

b. The lines do not appear to be perpendicular.



c. The lines appear to be perpendicular. The calculator screen is rectangular and does not have the same width and height. This causes the scale of the x–axis to differ from the scale on the y–axis despite using the same scale in the window settings. In part (b), this causes the lines not to appear perpendicular when indeed they are. The zoom square feature compensates for this and in part (c), the lines appear to be perpendicular.



38. makes sense

39. makes sense

40. does not make sense; Explanations will vary. Sample explanation: Slopes can be used for segments of the graph.

41. makes sense

42. Write $Ax+By+C=0$ in slope-intercept form.

$$Ax+By+C=0$$
$$By=-Ax-C$$
$$\frac{By}{B}=\frac{-Ax}{B}-\frac{C}{B}$$
$$y=-\frac{A}{B}x-\frac{C}{B}$$

The slope of the given line is $-\frac{A}{B}$.

The slope of any line perpendicular to $Ax+By+C=0$ is $\frac{B}{A}$.

43. The slope of the line containing $(1,-3)$ and $(-2,4)$ has slope $m=\frac{4-(-3)}{-2-1}=\frac{4+3}{-3}=\frac{7}{-3}=-\frac{7}{3}$

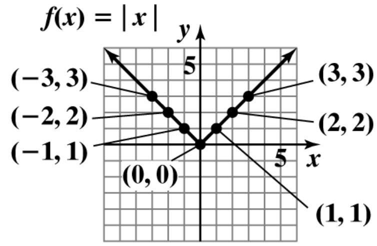
Solve $Ax+y-2=0$ for y to obtain slope-intercept form.

$$Ax+y-2=0$$
$$y=-Ax+2$$

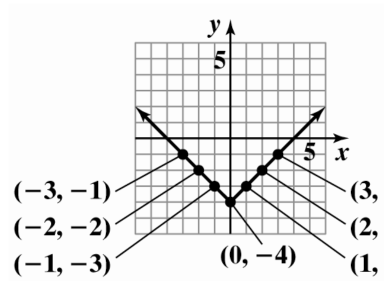
So the slope of this line is $-A$.

This line is perpendicular to the line above so its slope is $\frac{3}{7}$. Therefore, $-A=\frac{3}{7}$ so $A=-\frac{3}{7}$.

44. **a.**

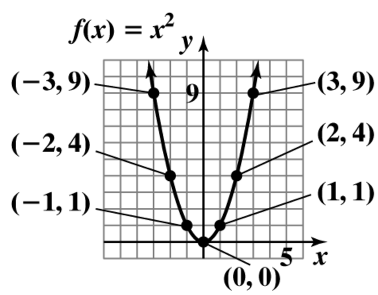


b.

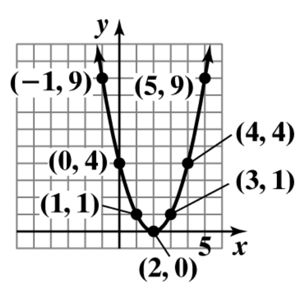


c. The graph in part (b) is the graph in part (a) shifted down 4 units.

45. **a.**

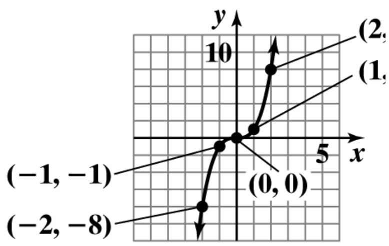


b.

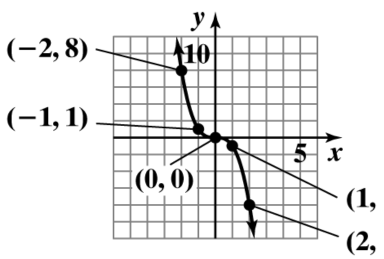


c. The graph in part (b) is the graph in part (a) shifted to the right 2 units.

46. **a.**



b.



c. The graph in part (b) is the graph in part (a) reflected across the y-axis.

Mid-Chapter 2 Check Point

1. The relation is not a function.
The domain is $\{1, 2\}$.
The range is $\{-6, 4, 6\}$.

2. The relation is a function.
The domain is $\{0, 2, 3\}$.
The range is $\{1, 4\}$.

3. The relation is a function.
The domain is $\{x \mid -2 \le x < 2\}$.
The range is $\{y \mid 0 \le y \le 3\}$.

4. The relation is not a function.
The domain is $\{x \mid -3 < x \le 4\}$.
The range is $\{y \mid -1 \le y \le 2\}$.

5. The relation is not a function.
The domain is $\{-2, -1, 0, 1, 2\}$.
The range is $\{-2, -1, 1, 3\}$.

6. The relation is a function.
The domain is $\{x \mid x \le 1\}$.
The range is $\{y \mid y \ge -1\}$.

7. $x^2 + y = 5$

$y = -x^2 + 5$

For each value of x, there is one and only one value for y, so the equation defines y as a function of x.

8. $x + y^2 = 5$

$y^2 = 5 - x$

$y = \pm\sqrt{5 - x}$

Since there are values of x that give more than one value for y (for example, if $x = 4$, then $y = \pm\sqrt{5-4} = \pm 1$), the equation does not define y as a function of x.

9. No vertical line intersects the graph in more than one point. Each value of x corresponds to exactly one value of y.

10. Domain: $(-\infty, \infty)$

11. Range: $(-\infty, 4]$

12. x-intercepts: –6 and 2

13. y-intercept: 3

14. increasing: $(-\infty, -2)$

15. decreasing: $(-2, \infty)$

16. $x = -2$

17. $f(-2) = 4$

18. $f(-4) = 3$

19. $f(-7) = -2$ and $f(3) = -2$

20. $f(-6) = 0$ and $f(2) = 0$

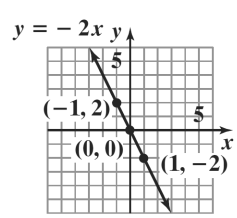
21. $(-6, 2)$

22. $f(100)$ is negative.

23. neither; $f(-x) \ne x$ and $f(-x) \ne -x$

24. $\dfrac{f(x_2) - f(x_1)}{x_2 - x_1} = \dfrac{f(4) - f(-4)}{4 - (-4)} = \dfrac{-5-3}{4+4} = -1$

25.



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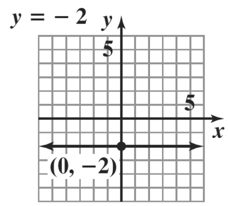

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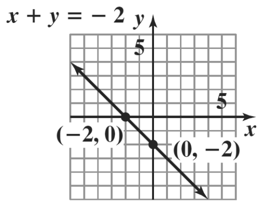

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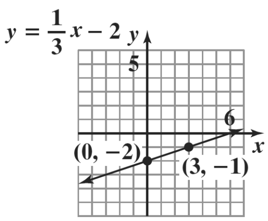

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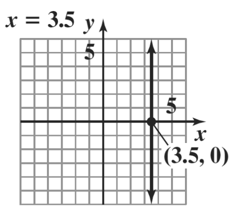

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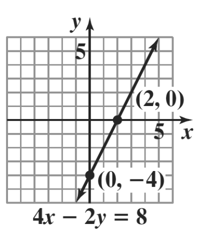
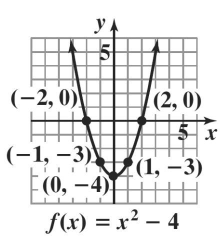


31.



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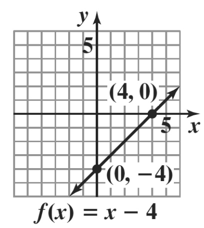

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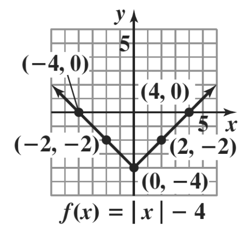
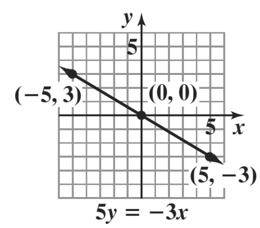


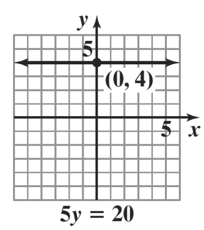
34. $5y = -3x$

$y = -\dfrac{3}{5}x$

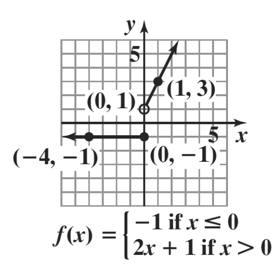


35. $5y = 20$

$y = 4$



36.



37. **a.** $f(-x) = -2(-x)^2 - x - 5$
$= -2x^2 - x - 5$
neither; $f(-x) \neq x$ and $f(-x) \neq -x$

b. $\dfrac{f(x+h) - f(x)}{h}$
$= \dfrac{-2(x+h)^2 + (x+h) - 5 - (-2x^2 + x - 5)}{h}$
$= \dfrac{-2x^2 - 4xh - 2h^2 + x + h - 5 + 2x^2 - x + 5}{h}$
$= \dfrac{-4xh - 2h^2 + h}{h}$
$= \dfrac{h(-4x - 2h + 1)}{h}$
$= -4x - 2h + 1$

38. $C(x) = \begin{cases} 30 & \text{if } 0 \leq t \leq 200 \\ 30 + 0.40(t - 200) & \text{if } t > 200 \end{cases}$

a. $C(150) = 30$

b. $C(250) = 30 + 0.40(250 - 200) = 50$

39. $y - y_1 = m(x - x_1)$
$y - 3 = -2(x - (-4))$
$y - 3 = -2(x + 4)$
$y - 3 = -2x - 8$
$y = -2x - 5$
$f(x) = -2x - 5$

40. $m = \dfrac{\text{Change in } y}{\text{Change in } x} = \dfrac{1 - (-5)}{2 - (-1)} = \dfrac{6}{3} = 2$
$y - y_1 = m(x - x_1)$
$y - 1 = 2(x - 2)$
$y - 1 = 2x - 4$
$y = 2x - 3$
$f(x) = 2x - 3$

41. $3x - y - 5 = 0$
$-y = -3x + 5$
$y = 3x - 5$

The slope of the given line is 3, and the lines are parallel, so $m = 3$.
$y - y_1 = m(x - x_1)$
$y - (-4) = 3(x - 3)$
$y + 4 = 3x - 9$
$y = 3x - 13$
$f(x) = 3x - 13$

42. $2x - 5y - 10 = 0$
$-5y = -2x + 10$
$\dfrac{-5y}{-5} = \dfrac{-2x}{-5} + \dfrac{10}{-5}$
$y = \dfrac{2}{5}x - 2$

The slope of the given line is $\dfrac{2}{5}$, and the lines are perpendicular, so $m = -\dfrac{5}{2}$.
$y - y_1 = m(x - x_1)$
$y - (-3) = -\dfrac{5}{2}(x - (-4))$
$y + 3 = -\dfrac{5}{2}x - 10$
$y = -\dfrac{5}{2}x - 13$
$f(x) = -\dfrac{5}{2}x - 13$

43. $m_1 = \dfrac{\text{Change in } y}{\text{Change in } x} = \dfrac{0 - (-4)}{7 - 2} = \dfrac{4}{5}$
$m_2 = \dfrac{\text{Change in } y}{\text{Change in } x} = \dfrac{6 - 2}{1 - (-4)} = \dfrac{4}{5}$
The slope of the lines are equal thus the lines are parallel.

44. **a.** $m = \dfrac{\text{Change in } y}{\text{Change in } x} = \dfrac{42 - 26}{180 - 80} = \dfrac{16}{100} = 0.16$

b. For each minute of brisk walking, the percentage of patients with depression in remission increased by 0.16%. The rate of change is 0.16% per minute of brisk walking.

45. $\dfrac{f(x_2) - f(x_1)}{x_2 - x_1} = \dfrac{f(2) - f(-1)}{2 - (-1)}$
$= \dfrac{\left(3(2)^2 - 2\right) - \left(3(-1)^2 - (-1)\right)}{2 + 1}$
$= 2$