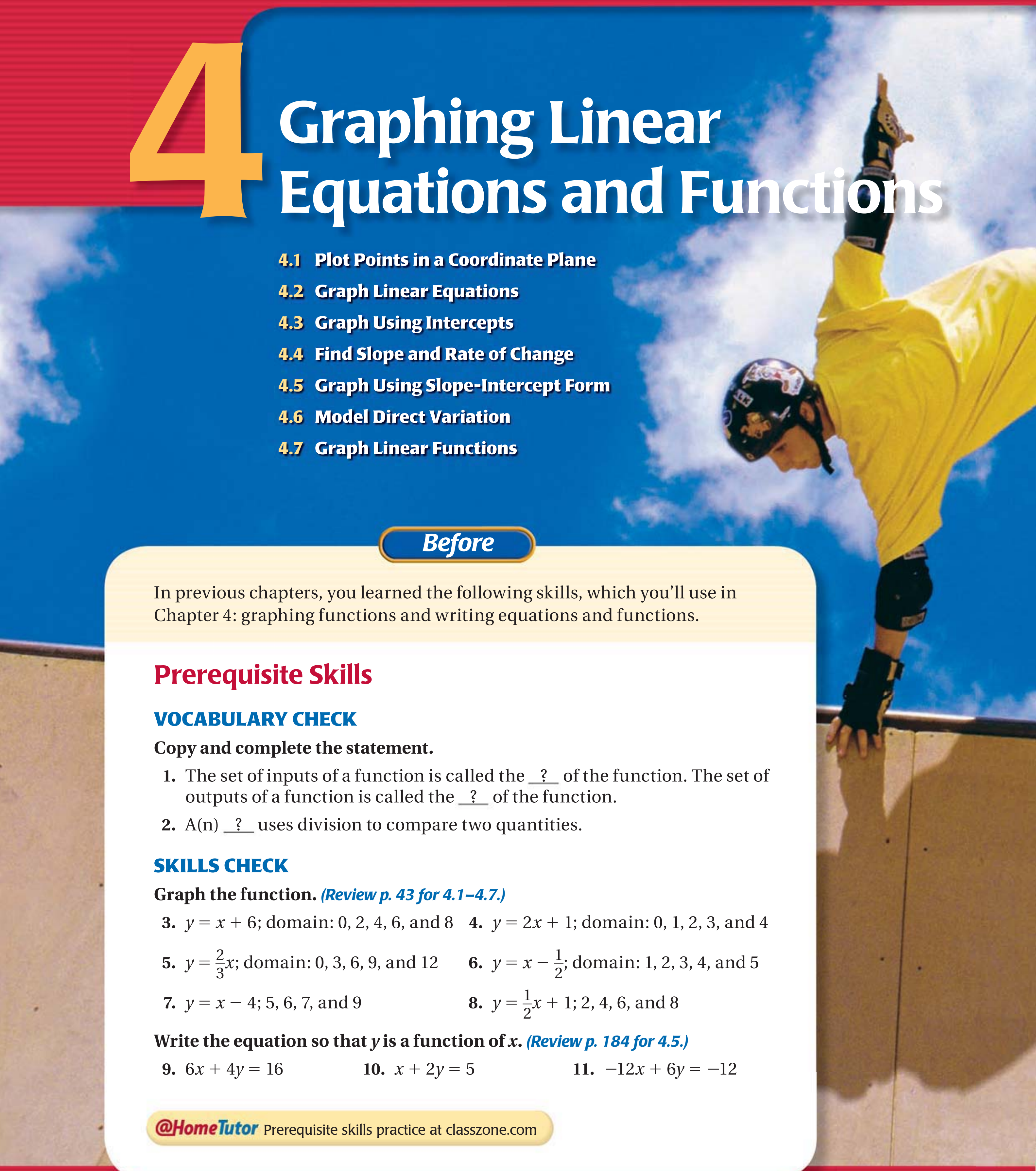


4 Graphing Linear Equations and Functions

Before

In previous chapters, you learned the following skills, which you'll use in Chapter 4: graphing functions and writing equations and functions.

Prerequisite Skills

VOCABULARY CHECK

Copy and complete the statement.

1. The set of inputs of a function is called the __?__ of the function. The set of outputs of a function is called the __?__ of the function.
2. A(n) __?__ uses division to compare two quantities.

SKILLS CHECK

Graph the function. *(Review p. 43 for 4.1–4.7.)*

3. $y = x + 6$; domain: 0, 2, 4, 6, and 8
4. $y = 2x + 1$; domain: 0, 1, 2, 3, and 4
5. $y = \frac{2}{3}x$; domain: 0, 3, 6, 9, and 12
6. $y = x - \frac{1}{2}$; domain: 1, 2, 3, 4, and 5
7. $y = x - 4$; 5, 6, 7, and 9
8. $y = \frac{1}{2}x + 1$; 2, 4, 6, and 8

Write the equation so that y is a function of x. *(Review p. 184 for 4.5.)*

9. $6x + 4y = 16$
10. $x + 2y = 5$
11. $-12x + 6y = -12$

@HomeTutor Prerequisite skills practice at classzone.com

Now

In Chapter 4, you will apply the big ideas listed below and reviewed in the Chapter Summary on page 270. You will also use the key vocabulary listed below.

Big Ideas

1. **Graphing linear equations and functions using a variety of methods**
2. **Recognizing how changes in linear equations and functions affect their graphs**
3. **Using graphs of linear equations and functions to solve real-world problems**

KEY VOCABULARY

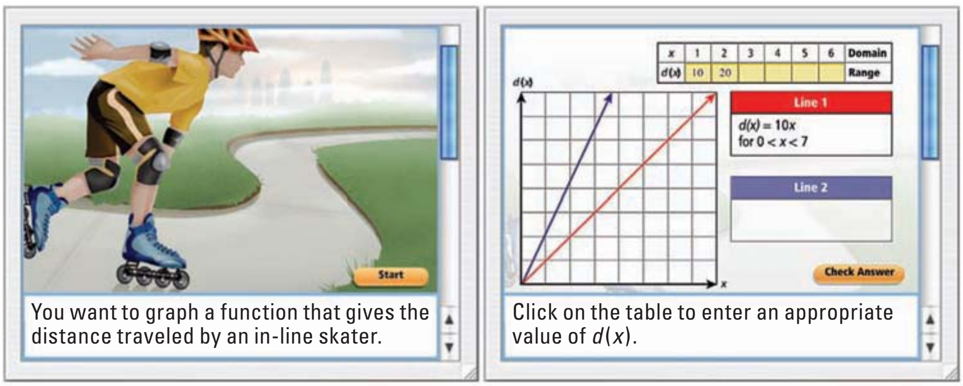
- quadrant, *p. 206*
- standard form of a linear equation, *p. 216*
- linear function, *p. 217*
- *x*-intercept, *p. 225*
- *y*-intercept, *p. 225*
- slope, *p. 235*
- rate of change, *p. 237*
- slope-intercept form, *p. 244*
- parallel, *p. 246*
- direct variation, *p. 253*
- constant of variation, *p. 253*
- function notation, *p. 262*
- family of functions, *p. 263*
- parent linear function, *p. 263*

Why?

You can graph linear functions to solve problems involving distance. For example, you can graph a linear function to find the time it takes and in-line skater to travel a particular distance at a particular speed.

Animated Algebra

The animation illustrated below for Exercise 41 on page 267 helps you answer this question: How can you graph a function that models the distance an in-line skater travels over time?



You want to graph a function that gives the distance traveled by an in-line skater.

Click on the table to enter an appropriate value of $d(x)$.

Animated Algebra at classzone.com

Other animations for Chapter 4: pages 207, 216, 226, 238, 245, and 254

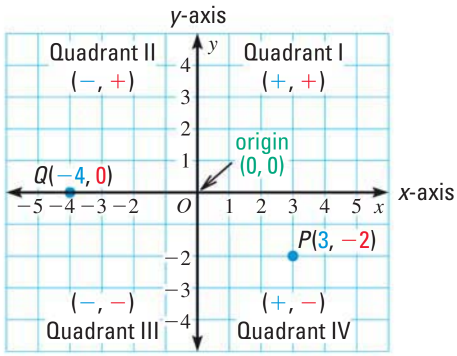
4.1 Plot Points in a Coordinate Plane

Before	You graphed numbers on a number line.
Now	You will identify and plot points in a coordinate plane.
Why?	So you can interpret photos of Earth taken from space, as in Ex. 36.

Key Vocabulary
- **quadrants**
- **coordinate plane,** *p. 921*
- **ordered pair,** *p. 921*

In Chapter 1, you used a coordinate plane to graph ordered pairs whose coordinates were nonnegative. If you extend the x-axis and y-axis to include negative values, you divide the coordinate plane into four regions called **quadrants**, labeled I, II, III, and IV as shown.

Points in Quadrant I have two positive coordinates. Points in the other three quadrants have at least one negative coordinate.



READING

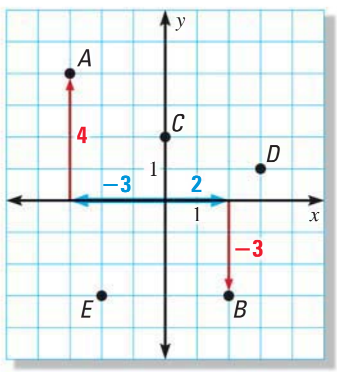
The x-coordinate of a point is sometimes called the *abscissa*. The y-coordinate of a point is sometimes called the *ordinate*.

For example, point P is in Quadrant IV and has an x-coordinate of 3 and a y-coordinate of -2. A point on an axis, such as point Q, is not considered to be in any of the four quadrants.

EXAMPLE 1 Name points in a coordinate plane

Give the coordinates of the point.

a. A **b.** B



Solution

a. Point A is 3 units to the left of the origin and 4 units up. So, the x-coordinate is -3, and the y-coordinate is 4. The coordinates are $(-3, 4)$.

b. Point B is 2 units to the right of the origin and 3 units down. So, the x-coordinate is 2, and the y-coordinate is -3. The coordinates are $(2, -3)$.

✓ GUIDED PRACTICE for Example 1

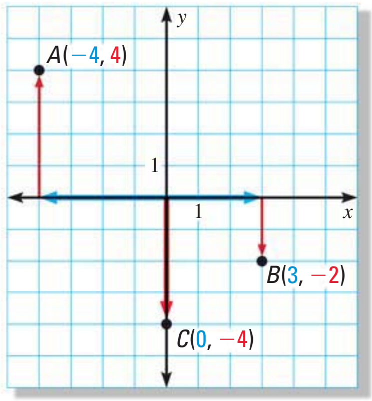
1. Use the coordinate plane in Example 1 to give the coordinates of points C, D, and E.
2. What is the y-coordinate of any point on the x-axis?

EXAMPLE 2 Plot points in a coordinate plane

Plot the point in a coordinate plane. Describe the location of the point.

a. $A(-4, 4)$ **b.** $B(3, -2)$ **c.** $C(0, -4)$

Solution



a. Begin at the origin. First move 4 units to the left, then 4 units up. Point A is in Quadrant II.

b. Begin at the origin. First move 3 units to the right, then 2 units down. Point B is in Quadrant IV.

c. Begin at the origin and move 4 units down. Point C is on the y-axis.

Animated Algebra at classzone.com

EXAMPLE 3 Graph a function

Graph the function $y = 2x - 1$ with domain $-2, -1, 0, 1$, and 2. Then identify the range of the function.

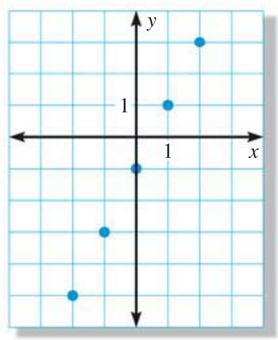
ANALYZE A FUNCTION
The function in Example 3 is called a *discrete* function. To learn about discrete functions, see p. 223.

Solution

STEP 1 **Make** a table by substituting the domain values into the function.

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

STEP 2 **List** the ordered pairs: $(-2, -5)$, $(-1, -3)$, $(0, -1)$, $(1, 1)$, $(2, 3)$. Then graph the function.



STEP 3 **Identify** the range. The range consists of the y-values from the table: $-5, -3, -1, 1$, and 3.

✓ GUIDED PRACTICE for Examples 2 and 3

Plot the point in a coordinate plane. *Describe* the location of the point.

3. $A(2, 5)$ **4.** $B(-1, 0)$ **5.** $C(-2, -1)$ **6.** $D(-5, 3)$

7. Graph the function $y = -\frac{1}{3}x + 2$ with domain $-6, -3, 0, 3$, and 6. Then identify the range of the function.

EXAMPLE 4 Graph a function represented by a table

Presidential campaign button

VOTING In 1920 the ratification of the 19th amendment to the United States Constitution gave women the right to vote. The table shows the number (to the nearest million) of votes cast in presidential elections both before and since women were able to vote.

−4 means 4 years before 1920, or 1916.

0 represents the year 1920.

Years before or since 1920	−12	−8	−4	0	4	8	12
Votes (millions)	15	15	19	27	29	37	40

a. Explain how you know that the table represents a function.

b. Graph the function represented by the table.

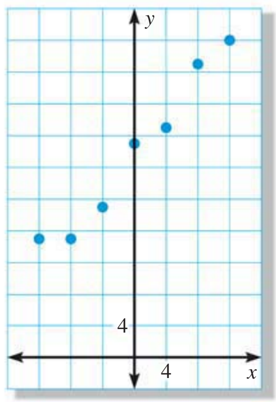
c. Describe any trend in the number of votes cast.

Solution

a. The table represents a function because each input has exactly one output.

b. To graph the function, let x be the number of years before or since 1920. Let y be the number of votes cast (in millions).

The graph of the function is shown.



c. In the three election years before 1920, the number of votes cast was less than 20 million. In 1920, the number of votes cast was greater than 20 million. The number of votes cast continued to increase in the three election years since 1920.

✓ GUIDED PRACTICE for Example 4

8. VOTING The presidential election in 1972 was the first election in which 18-year-olds were allowed to vote. The table shows the number (to the nearest million) of votes cast in presidential elections both before and since 1972.

Years before or since 1972	−12	−8	−4	0	4	8	12
Votes (millions)	69	71	73	78	82	87	93

a. *Explain* how you know the graph represents a function.

b. Graph the function represented by the table.

c. *Describe* any trend in the number of votes cast.

4.1 EXERCISES

HOMEWORK KEY

○ = **WORKED-OUT SOLUTIONS** on p. WS1 for Exs. 15, 25, and 37

★ = **STANDARDIZED TEST PRACTICE** Exs. 2, 13, 23, 33, and 41

◆ = **MULTIPLE REPRESENTATIONS** Ex. 40

SKILL PRACTICE

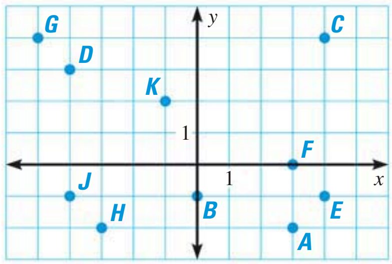
1. **VOCABULARY** What is the x-coordinate of the point $(5, -3)$? What is the y-coordinate?

2. ★ **WRITING** One of the coordinates of a point is negative while the other is positive. Can you determine the quadrant in which the point lies? *Explain.*

EXAMPLE 1
on p. 206
for Exs. 3–13

NAMING POINTS **Give the coordinates of the point.**

3. A
4. B
5. C
6. D
7. E
8. F
9. G
10. H
11. J
12. K



13. ★ **MULTIPLE CHOICE** A point is located 3 units to the left of the origin and 6 units up. What are the coordinates of the point?

   Ⓐ $(3, 6)$ Ⓑ $(-3, 6)$ Ⓒ $(6, 3)$ Ⓓ $(6, -3)$

EXAMPLE 2
on p. 207
for Exs. 14–22

PLOTTING POINTS **Plot the point in a coordinate plane. *Describe* the location of the point.**

14. $P(5, 5)$
15. $Q(-1, 5)$
16. $R(-3, 0)$
17. $S(0, 0)$
18. $T(-3, -4)$
19. $U(0, 6)$
20. $V(1.5, 4)$
21. $W(3, -2.5)$

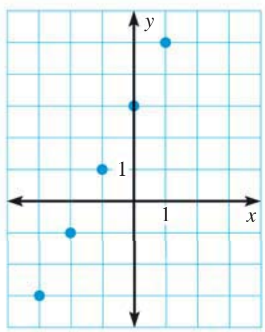
22. **ERROR ANALYSIS** *Describe* and correct the error in describing the location of the point $W(6, -6)$.

Point $W(6, -6)$ is 6 units to the left of the origin and 6 units up.

EXAMPLE 3
on p. 207
for Exs. 23–27

23. ★ **MULTIPLE CHOICE** Which number is in the range of the function whose graph is shown?

   Ⓐ -2 Ⓑ -1
   Ⓒ 0 Ⓓ 2



GRAPHING FUNCTIONS **Graph the function with the given domain. Then identify the range of the function.**

24. $y = -x + 1$; domain: $-2, -1, 0, 1, 2$

25. $y = 2x - 5$; domain: $-2, -1, 0, 1, 2$

26. $y = -\frac{2}{3}x - 1$; domain: $-6, -3, 0, 3, 6$

27. $y = \frac{1}{2}x + 1$; domain: $-6, -4, -2, 0, 2$

28. **GEOMETRY** Plot the points $W(-4, -2)$, $X(-4, 4)$, $Y(4, 4)$, and $Z(4, -2)$ in a coordinate plane. Connect the points in order. Connect point Z to point W. Identify the resulting figure. Find its perimeter and area.

REASONING **Without plotting the point, tell whether it is in Quadrant I, II, III, or IV. *Explain* your reasoning.**

29. $(4, -11)$

30. $(40, -40)$

31. $(-18, 15)$

32. $(-32, -22)$

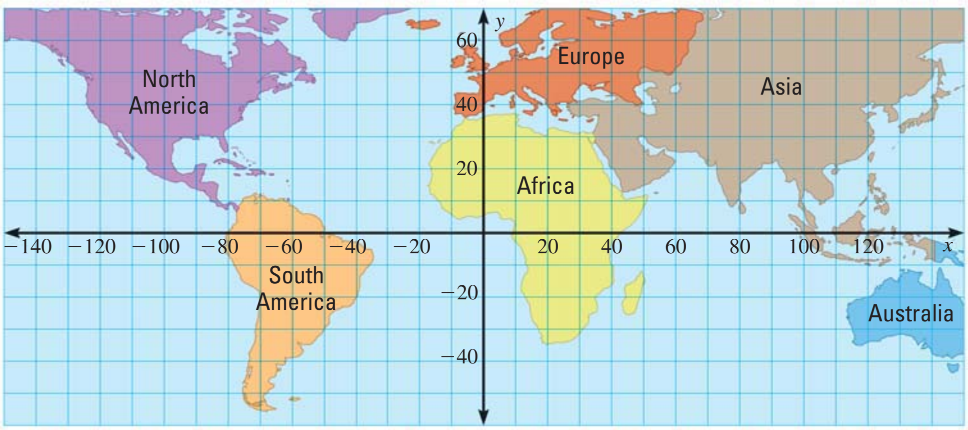
33. ★ **WRITING** *Explain* how can you tell by looking at the coordinates of a point whether the point is on the x-axis or on the y-axis.

34. **REASONING** Plot the point $J(-4, 3)$ in a coordinate plane. Plot three additional points in the same coordinate plane so that each of the four points lies in a different quadrant and the figure formed by connecting the points is a square. *Explain* how you located the points.

35. **CHALLENGE** Suppose the point (a, b) lies in Quadrant IV. *Describe* the location of the following points: (b, a), $(2a, -2b)$, and $(-b, -a)$. *Explain* your reasoning.

PROBLEM SOLVING

36. **ASTRONAUT PHOTOGRAPHY** Astronauts use a coordinate system to describe the locations of objects they photograph from space. The x-axis is the equator, 0° latitude. The y-axis is the prime meridian, 0° longitude. The names and coordinates of some lakes photographed from space are given. Use the map to determine on which continent each lake is located.



a. Lake Kulundinskoye: (80, 53)

b. Lake Champlain: (−73, 45)

c. Lake Van: (43, 39)

d. Lake Viedma: (−73, −50)

e. Lake Saint Clair: (−83, 43)

f. Starnberger Lake: (12, 48)

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EXAMPLE 4
on p. 208
for Exs. 37–39

37. **RECORD TEMPERATURES** The table shows the record low temperatures (in degrees Fahrenheit) for Odessa, Texas, for each day in the first week of February. *Explain* how you know the table represents a function. Graph the data from the table.

Day in February	1	2	3	4	5	6	7
Record low (degrees Fahrenheit)	−8	−11	10	8	10	9	11

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38. **STOCK VALUE** The table shows the change in value (in dollars) of a stock over five days.

Day	1	2	3	4	5
Change in value (dollars)	−0.30	0.10	0.15	0.35	0.11

a. *Explain* how you know the table represents a function. Graph the data from the table.

b. *Describe* any trend in the change in value of the stock.

39. **MULTI-STEP PROBLEM** The difference between what the federal government collects and what it spends during a fiscal year is called the federal surplus or deficit. The table shows the federal surplus or deficit (in billions of dollars) in the 1990s. (A negative number represents a deficit.)

Years since 1990	0	1	2	3	4	5	6	7	8	9
Surplus or deficit (billions)	−221	−269	−290	−255	−203	−164	−108	−22	69	126

a. Graph the function represented by the table.

b. What conclusions can you make from the graph?

40. **MULTIPLE REPRESENTATIONS** Low-density lipoproteins (LDL) transport cholesterol in the bloodstream throughout the body. A high LDL number is associated with an increased risk of cardiovascular disease. A patient's LDL number in 1999 was 189 milligrams per deciliter (mg/dL). To lower that number, the patient went on a diet. The annual LDL numbers for the patient in years after 1999 are 169, 154, 145, 139, and 136.

Years since 1999	1	2	?	?	?
Changes in LDL (mg/dL)	−20	−15	?	?	?

a. Making a Table Use the given information to copy and complete the table that shows the change in the patient's LDL number since 1999.

b. Drawing a Graph Graph the ordered pairs from the table.

c. Describing in Words Based on the graph, what can you conclude about the diet's effectiveness in lowering the patient's LDL number?

41. ★ **EXTENDED RESPONSE** In a scientific study, researchers asked men to report their heights and weights. Then the researchers measured the actual heights and weights of the men. The data for six men are shown in the table. One row of the table represents the data for one man.

Height (inches)			Weight (pounds)		
Reported	**Measured**	**Difference**	**Reported**	**Measured**	**Difference**
70	68	$70 - 68 = 2$	154	146	$154 - 146 = 8$
70	67.5	?	141	143	?
78.5	77.5	?	165	168	?
68	69	?	146	143	?
71	72	?	220	223	?
70	70	?	176	176	?

a. **Calculate** Copy and complete the table.

b. **Graph** For each participant, write an ordered pair (x, y) where x is the difference of the reported and measured heights and y is the difference of the reported and measured weights. Then plot the ordered pairs in a coordinate plane.

c. **CHALLENGE** What does the origin represent in this situation?

d. **CHALLENGE** Which quadrant has the greatest number of points? *Explain* what it means for a point to be in that quadrant.

MIXED REVIEW

Evaluate the expression.

42. $4 + 2x^2$ when $x = 6$ *(p. 2)*

43. $6 \cdot 2a^2$ when $a = 3$ *(p. 2)*

44. $4 + 2(-7) + 3$ *(p. 8)*

45. $3(35 - 18)$ *(p. 8)*

Use the distributive property to write an equivalent expression. *(p. 96)*

46. $6(x + 20)$

47. $3x(x + 9)$

48. $-(4 - 5y)$

49. **TRAVEL** You are traveling on the highway at an average speed of 55 miles per hour. How long will it take you to drive 66 miles? *(p. 168)*

PREVIEW
Prepare for Lesson 4.2 in Exs. 50–54.

Write the equation so that y is a function of x. *(p. 184)*

50. $4x + y = 6$

51. $x + 7y = 14$

52. $4(y - 6x) = 12$

Tell whether the pairing is a function. *(p. 35)*

53.

Input	−5	−4	−3	−2
Output	−2	0	2	4

54.

Input	−1	0	1	2
Output	10	10	4	1

Extension

Use after Lesson 4.1

Perform Transformations

GOAL Perform and describe transformations in a coordinate plane.

Key Vocabulary
- **transformation**
- **translation**
- **vertical stretch or shrink**
- **reflection**

For a given set of points, a **transformation** produces an image by applying a rule to the coordinates of the points. Some types of transformations are *translations, vertical stretches, vertical shrinks*, and *reflections*.

A **translation** moves every point in a figure the same distance in the same direction either horizontally, vertically, or both. You can describe translations algebraically.

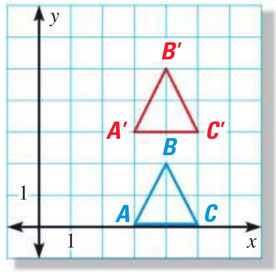
Horizontal translation: $(x, y) \to (x + h, y)$ **Vertical translation:** $(x, y) \to (x, y + k)$

EXAMPLE 1 Perform a translation

The transformation $(x, y) \to (x, y + 3)$ moves $\triangle ABC$ up 3 units.

Original		**Image**
$A(3, 0)$	$\to$	$A'(3, 3)$
$B(4, 2)$	$\to$	$B'(4, 5)$
$C(5, 0)$	$\to$	$C'(5, 3)$

The result of the transformation is $\triangle A'B'C'$.



READ TRANSFORMATIONS
If a transformation is performed on a point *A*, the new location of point *A* is indicated by *A′* (read "*A* prime").

A **vertical stretch or shrink** moves every point in a figure away from the x-axis (a vertical stretch) or toward the x-axis (a vertical shrink), while points on the x-axis remain fixed. A **reflection** flips a figure in a line. You can describe vertical stretches and shrinks with or without reflection in the x-axis algebraically.

Vertical stretch:
$(x, y) \to (x, ay)$ where $a > 1$

Vertical shrink:
$(x, y) \to (x, ay)$ where $0 < a < 1$

Vertical stretch with reflection in the x-axis:
$(x, y) \to (x, ay)$ where $a < -1$

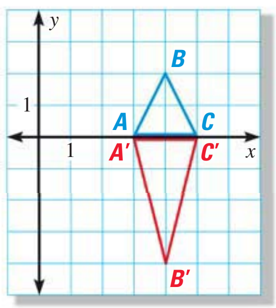
Vertical shrink with reflection in the x-axis:
$(x, y) \to (x, ay)$ where $-1 < a < 0$

EXAMPLE 2 Perform a vertical stretch with reflection

The transformation $(x, y) \to (x, -2y)$ vertically stretches $\triangle ABC$ and reflects it in the x-axis.

Original		**Image**
$A(3, 0)$	$\to$	$A'(3, 0)$
$B(4, 2)$	$\to$	$B'(4, -4)$
$C(5, 0)$	$\to$	$C'(5, 0)$

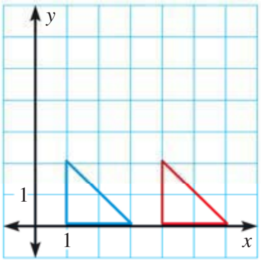
The result of the transformation is $\triangle A'B'C'$.

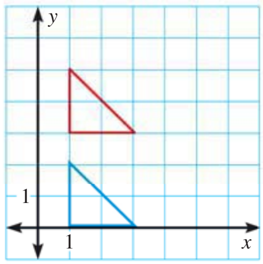


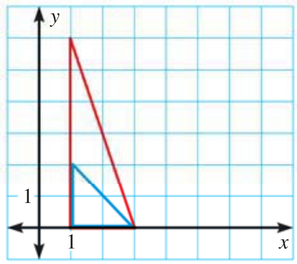
CONCEPT SUMMARY *For Your Notebook*

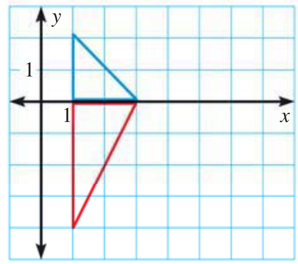
Identifying Transformations

Translation		Vertical stretch or shrink	
Horizontal	**Vertical**	**Without reflection**	**With reflection**
$(x, y) \to (x + h, y)$	$(x, y) \to (x, y + k)$	$(x, y) \to (x, ay)$ where $a > 0$	$(x, y) \to (x, ay)$ where $a < 0$









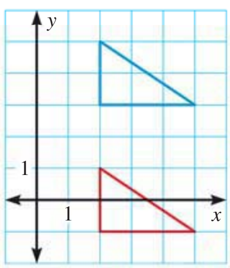
PRACTICE

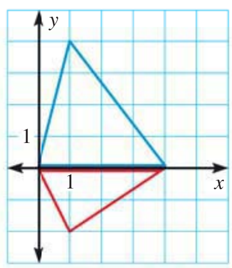
1. **VOCABULARY** Does a translation or a vertical stretch always produce a figure that is the same size and shape as the original figure? *Explain*.

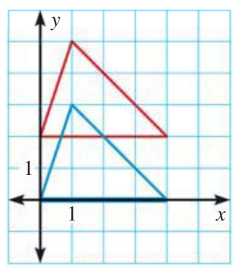
2. ★ **WRITING** *Describe* the vertical shrink $(x, y) \to (x, \frac{1}{2}y)$ in words.

EXAMPLES 1 and 2 on p. 213 for Exs. 3–14

DESCRIBING TRANSFORMATIONS **Use words to describe the transformation of the blue figure to the red figure.**

3. 

4. 

5. 

PERFORMING TRANSFORMATIONS **Square *ABCD* has vertices at (0, 0), (0, 2), (2, 2), and (2, 0). Perform the indicated transformation. Then give the coordinates of figure *A′B′C′D′*.**

6. $(x, y) \to (x, y - 5)$
7. $(x, y) \to (x, y + 1)$
8. $(x, y) \to (x, y - 7)$
9. $(x, y) \to (x, -y)$
10. $(x, y) \to (x, 4y)$
11. $(x, y) \to (x, -\frac{1}{2}y)$
12. $(x, y) \to (x + 2, y + 3)$
13. $(x, y) \to (x - 1, y + 4)$
14. $(x, y) \to (x + 3, y)$

15. ★ **WRITING** A square has vertices at (0, 0), (0, 3), (3, 3), and (3, 0). Tell how you could use a transformation to move the square so that it has new vertices at (0, 0), (0, −3), (3, −3), and (3, 0).

4.2 Graph Linear Equations

Before You plotted points in a coordinate plane.

Now You will graph linear equations in a coordinate plane.

Why? So you can find how meteorologists collect data, as in Ex. 40.

Key Vocabulary
- **standard form of a linear equation**
- **linear function**

An example of an equation in two variables is $2x + 5y = 8$. A **solution of an equation in two variables**, x and y, is an ordered pair (x, y) that produces a true statement when the values of x and y are substituted into the equation.

EXAMPLE 1 Standardized Test Practice

Which ordered pair is a solution of $3x - y = 7$?

Ⓐ (3, 4) Ⓑ (1, −4) Ⓒ (5, −3) Ⓓ (−1, −2)

Solution

Check whether each ordered pair is a solution of the equation.

Test (3, 4): $3x - y = 7$ **Write original equation.**

$3(3) - 4 \stackrel{?}{=} 7$ **Substitute 3 for x and 4 for y.**

$5 = 7$ ✗ **Simplify.**

Test (1, −4): $3x - y = 7$ **Write original equation.**

$3(1) - (-4) \stackrel{?}{=} 7$ **Substitute 1 for x and −4 for y.**

$7 = 7$ ✓ **Simplify.**

So, (3, 4) is *not* a solution, but (1, −4) is a solution of $3x - y = 7$.

▶ The correct answer is B. Ⓐ Ⓑ Ⓒ Ⓓ

✓ GUIDED PRACTICE for Example 1

1. Tell whether $\left(4, -\frac{1}{2}\right)$ is a solution of $x + 2y = 5$.

GRAPHS The **graph of an equation in two variables** is the set of points in a coordinate plane that represent all solutions of the equation. If the variables in an equation represent real numbers, one way to graph the equation is to make a table of values, plot enough points to recognize a pattern, and then connect the points. When making a table of values, choose convenient values of x that include negative values, zero, and positive values.

EXAMPLE 2 Graph an equation

Graph the equation $-2x + y = -3$.

Solution

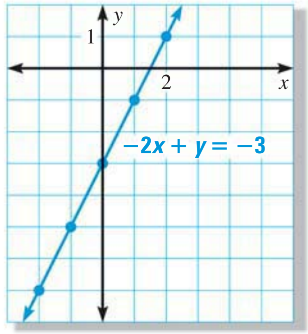
STEP 1 **Solve** the equation for y.

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

$$y = 2x - 3$$

STEP 2 **Make** a table by choosing a few values for x and finding the values of y.

x	-2	-1	0	1	2
y	-7	-5	-3	-1	1



STEP 3 **Plot** the points. Notice that the points appear to lie on a line.

STEP 4 **Connect** the points by drawing a line through them. Use arrows to indicate that the graph goes on without end.

DRAW A GRAPH
If you continued to find solutions of the equation and plotted them, the line would fill in.

LINEAR EQUATIONS A **linear equation** is an equation whose graph is a line, such as the equation in Example 2. The **standard form** of a linear equation is

$$Ax + By = C$$

where A, B, and C are real numbers and A and B are not both zero.

Consider what happens when $A = 0$ or when $B = 0$. When $A = 0$, the equation becomes $By = C$, or $y = \frac{C}{B}$. Because $\frac{C}{B}$ is a constant, you can write $y = b$. Similarly, when $B = 0$, the equation becomes $Ax = C$, or $x = \frac{C}{A}$, and you can write $x = a$.

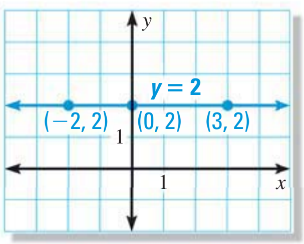
EXAMPLE 3 Graph $y = b$ and $x = a$

Graph (a) $y = 2$ and (b) $x = -1$.

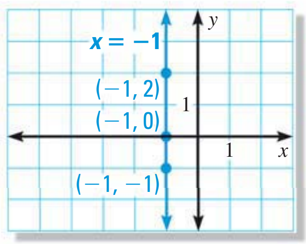
Solution

FIND A SOLUTION
The equations $y = 2$ and $0x + 1y = 2$ are equivalent. For any value of x, the ordered pair $(x, 2)$ is a solution of $y = 2$.

a. For every value of x, the value of y is 2. The graph of the equation $y = 2$ is a horizontal line 2 units above the x-axis.



b. For every value of y, the value of x is -1. The graph of the equation $x = -1$ is a vertical line 1 unit to the left of the y-axis.



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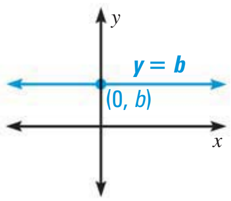
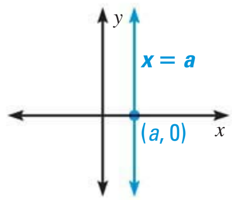
KEY CONCEPT — *For Your Notebook*

Equations of Horizontal and Vertical Lines



The graph of $y = b$ is a horizontal line. The line passes through the point $(0, b)$.



The graph of $x = a$ is a vertical line. The line passes through the point $(a, 0)$.

✓ GUIDED PRACTICE for Examples 2 and 3

Graph the equation.

2. $y + 3x = -2$

3. $y = 2.5$

4. $x = -4$

LINEAR FUNCTIONS In Example 3, $y = 2$ is a function, while $x = -1$ is not a function. The equation $Ax + By = C$ represents a **linear function** provided $B \neq 0$ (that is, provided the graph of the equation is not a vertical line). If the domain of a linear function is not specified, it is understood to be all real numbers. The domain can be restricted, as shown in Example 4.

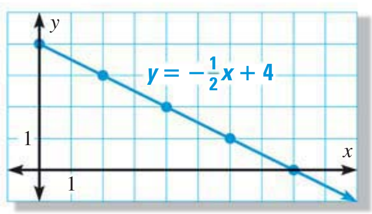
EXAMPLE 4 Graph a linear function

Graph the function $y = -\frac{1}{2}x + 4$ with domain $x \geq 0$. Then identify the range of the function.

Solution

STEP 1 **Make** a table.

x	0	2	4	6	8
y	4	3	2	1	0



STEP 2 **Plot** the points.

STEP 3 **Connect** the points with a ray because the domain is restricted.

STEP 4 **Identify** the range. From the graph, you can see that all points have a y-coordinate of 4 or less, so the range of the function is $y \leq 4$.

ANALYZE A FUNCTION

The function in Example 4 is called a *continuous* function. To learn about continuous functions, see p. 223.

✓ GUIDED PRACTICE for Example 4

5. Graph the function $y = -3x + 1$ with domain $x \leq 0$. Then identify the range of the function.

EXAMPLE 5 Solve a multi-step problem

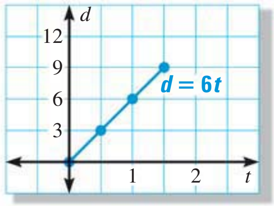
RUNNING The distance d (in miles) that a runner travels is given by the function $d = 6t$ where t is the time (in hours) spent running. The runner plans to go for a 1.5 hour run. Graph the function and identify its domain and range.

Solution

STEP 1 **Identify** whether the problem specifies the domain or the range. You know the amount of time the runner plans to spend running. Because time is the independent variable, the domain is specified in this problem. The domain of the function is $0 \le t \le 1.5$.

STEP 2 **Graph** the function. Make a table of values. Then plot and connect the points.

t (hours)	0	0.5	1	1.5
d (miles)	0	3	6	9



STEP 3 **Identify** the unspecified domain or range. From the table or graph, you can see that the range of the function is $0 \le d \le 9$.

ANALYZE GRAPHS
In Example 2, the domain is unrestricted, and the graph is a *line*. In Example 4, the domain is restricted to $x \ge 0$, and the graph is a *ray*. Here, the domain is restricted to $0 \le t \le 1.5$, and the graph is a *line segment*.

EXAMPLE 6 Solve a related problem

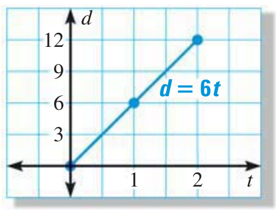
WHAT IF? Suppose the runner in Example 5 instead plans to run 12 miles. Graph the function and identify its domain and range.

Solution

STEP 1 **Identify** whether the problem specifies the domain or the range. You are given the distance that the runner plans to travel. Because distance is the dependent variable, the range is specified in this problem. The range of the function is $0 \le d \le 12$.

STEP 2 **Graph** the function. To make a table, you can substitute d-values (be sure to include 0 and 12) into the function $d = 6t$ and solve for t.

t (hours)	0	1	2
d (miles)	0	6	12



STEP 3 **Identify** the unspecified domain or range. From the table or graph, you can see that the domain of the function is $0 \le t \le 2$.

SOLVE FOR t
To find the time it takes the runner to run 12 miles, solve the equation $6t = 12$ to get $t = 2$.

✓ GUIDED PRACTICE for Examples 5 and 6

6. **GAS COSTS** For gas that costs \$2 per gallon, the equation $C = 2g$ gives the cost C (in dollars) of pumping g gallons of gas. You plan to pump \$10 worth of gas. Graph the function and identify its domain and range.

4.2 EXERCISES

HOMEWORK KEY

○ = **WORKED-OUT SOLUTIONS** on p. WS1 or Exs. 3, 11, and 37

★ = **STANDARDIZED TEST PRACTICE** Exs. 2, 10, 32, 33, 39, and 41

◆ = **MULTIPLE REPRESENTATIONS** Ex. 40

SKILL PRACTICE

1. **VOCABULARY** The equation $Ax + By = C$ represents a(n) __?__ provided $B \neq 0$.

2. ★ **WRITING** Is the equation $y = 6x + 4$ in standard form? *Explain.*

EXAMPLE 1 on p. 215 for Exs. 3–10

CHECKING SOLUTIONS **Tell whether the ordered pair is a solution of the equation.**

3. $2y + x = 4$; $(-2, 3)$
4. $3x - 2y = -5$; $(-1, 1)$
5. $x = 9$; $(9, 6)$
6. $y = -7$; $(-7, 0)$
7. $-7x - 4y = 1$; $(-3, -5)$
8. $-5y - 6x = 0$; $(-6, 5)$

9. **ERROR ANALYSIS** *Describe* and correct the error in determining whether (8, 11) is a solution of $y - x = -3$.

$y - x = -3$

$8 - 11 = -3$

$-3 = -3$ (8, 11) is a solution.

10. ★ **MULTIPLE CHOICE** Which ordered pair is a solution of $6x + 3y = 18$?

Ⓐ $(-2, -10)$ Ⓑ $(-2, 10)$ Ⓒ $(2, 10)$ Ⓓ $(10, -2)$

EXAMPLES 2 and 3 on p. 216 for Exs. 11–25

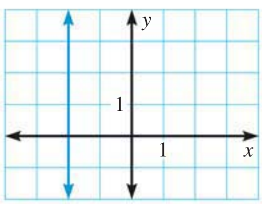
GRAPHING EQUATIONS **Graph the equation.**

11. $y + x = 2$
12. $y - 2x = 5$
13. $y - 3x = 0$
14. $y + 4x = 1$
15. $2y - 6x = 10$
16. $3y + 4x = 12$
17. $x - 2y = 3$
18. $3x + 2y = 8$
19. $x = 0$
20. $y = 0$
21. $y = -4$
22. $x = 2$

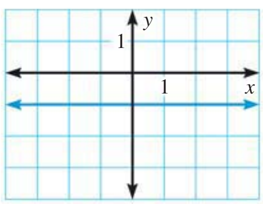
MATCHING EQUATIONS WITH GRAPHS **Match the equation with its graph.**

23. $y - x = 0$
24. $x = -2$
25. $y = -1$

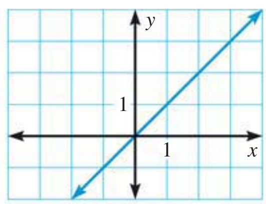
A.



B.



C.



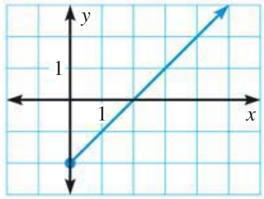
EXAMPLE 4 on p. 217 for Exs. 26–31

GRAPHING FUNCTIONS **Graph the function with the given domain. Then identify the range of the function.**

26. $y = 3x - 2$; domain: $x \geq 0$
27. $y = -5x + 3$; domain: $x \leq 0$
28. $y = 4$; domain: $x \leq 5$
29. $y = -6$; domain: $x \geq 5$
30. $y = 2x + 3$; domain: $-4 \leq x \leq 0$
31. $y = -x - 1$; domain: $-1 \leq x \leq 3$

32. ★ **OPEN-ENDED** Graph $x - y = 3$ and $2x - 2y = 6$. *Explain* why the equations look different but have the same graph. Find another equation that looks different from the two given equations but has the same graph.

33. ★ **MULTIPLE CHOICE** Which statement is true for the function whose graph is shown?



Ⓐ The domain is unrestricted.

Ⓑ The domain is $x \leq -2$.

Ⓒ The range is $y \leq -2$.

Ⓓ The range is $y \geq -2$.

34. **CHALLENGE** If $(3, n)$ is a solution of $Ax + 3y = 6$ and $(n, 5)$ is a solution of $5x + y = 20$, what is the value of A?

PROBLEM SOLVING

EXAMPLES 5 and 6 on p. 218 for Exs. 35–39

35. **BAKING** The weight w (in pounds) of a loaf of bread that a recipe yields is given by the function $w = \frac{1}{2}f$ where f is the number of cups of flour used. You have 4 cups of flour. Graph the function and identify its domain and range. What is the weight of the largest loaf of bread you can make?

36. **TRAVEL** After visiting relatives who live 200 miles away, your family drives home at an average speed of 50 miles per hour. Your distance d (in miles) from home is given by $d = 200 - 50t$ where t is the time (in hours) spent driving. Graph the function and identify its domain and range. What is your distance from home after driving for 1.5 hours?

37. **EARTH SCIENCE** The temperature T (in degrees Celsius) of Earth's crust can be modeled by the function $T = 20 + 25d$ where d is the distance (in kilometers) from the surface.

a. A scientist studies organisms in the first 4 kilometers of Earth's crust. Graph the function and identify its domain and range. What is the temperature at the deepest part of the section of crust?

b. Suppose the scientist studies organisms in a section of the crust where the temperature is between 20°C and 95°C. Graph the function and identify its domain and range. How many kilometers deep is the section of crust?

38. **MULTI-STEP PROBLEM** A fashion designer orders fabric that costs \$30 per yard. The designer wants the fabric to be dyed, which costs \$100. The total cost C (in dollars) of the fabric is given by the function

$$C = 30f + 100$$

where f is the number of yards of fabric.

a. The designer orders 3 yards of fabric. How much does the fabric cost? *Explain.*

b. Suppose the designer can spend \$500 on fabric. How many yards of fabric can the designer buy? *Explain.*

○ = WORKED-OUT SOLUTIONS on p. WS1 ★ = STANDARDIZED TEST PRACTICE ◆ = MULTIPLE REPRESENTATIONS

39. ★ **SHORT RESPONSE** An emergency cell phone charger requires you to turn a small crank in order to create the energy needed to recharge the phone's battery. If you turn the crank 120 times per minute, the total number r of revolutions that you turn the crank is given by

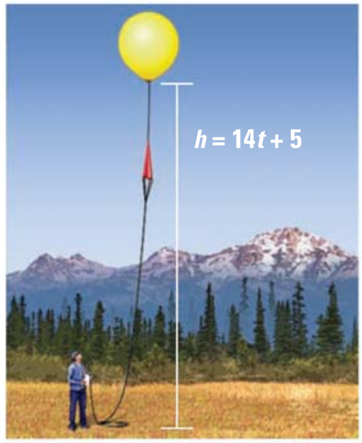
$$r = 120t$$

where t is the time (in minutes) spent turning the crank.

a. Graph the function and identify its domain and range.

b. Identify the domain and range if you stop turning the crank after 4 minutes. *Explain* how this affects the appearance of the graph.

40. **MULTIPLE REPRESENTATIONS** The National Weather Service releases weather balloons twice daily at over 90 locations in the United States in order to collect data for meteorologists. The height h (in feet) of a balloon is a function of the time t (in seconds) after the balloon is released, as shown.



a. Making a Table Make a table showing the height of a balloon after t seconds for $t = 0$ through $t = 10$.

b. Drawing a Graph A balloon bursts after a flight of about 7200 seconds. Graph the function and identify the domain and range.

41. ★ **EXTENDED RESPONSE** Students can pay for lunch at a school in one of two ways. Students can either make a payment of \$30 per month or they can buy lunch daily for \$2.50 per lunch.

a. Graph Graph the function $y = 30$ to represent the monthly payment plan. Using the same coordinate plane, graph the function $y = 2.5x$ to represent the daily payment plan.

b. CHALLENGE What are the coordinates of the point that is a solution of both functions? What does that point mean in this situation?

c. CHALLENGE A student eats an average of 15 school lunches per month. How should the student pay, daily or monthly? *Explain*.

MIXED REVIEW

Solve the equation.

42. $12x = 144$ *(p. 134)*

43. $-4x = 30$ *(p. 134)*

44. $5.7x - 2x = 14.8$ *(p. 141)*

45. $x - 4(x + 13) = 26$ *(p. 148)*

46. $6x - 4x + 13 = 27 - 2x$ *(p. 154)*

47. $5x - \frac{1}{4}(24 + 8x) = 2x - 5$ *(p. 154)*

PREVIEW
Prepare for Lesson 4.3 in Exs. 48–55.

Plot the point in a coordinate plane. *Describe* the location of the point. *(p. 206)*

48. $(3, 5)$

49. $(-3, 2)$

50. $(0, -2)$

51. $(-5, 0)$

52. $(-2, -2)$

53. $\left(\frac{1}{3}, 0\right)$

54. $\left(-\frac{1}{2}, \frac{3}{4}\right)$

55. $(0, 6.2)$

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Keystrokes

4.2 Graphing Linear Equations

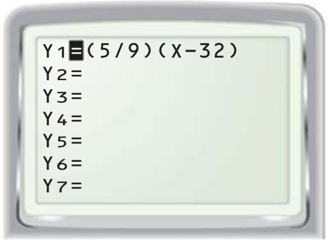
QUESTION How do you graph an equation on a graphing calculator?

EXAMPLE Use a graph to solve a problem

The formula to convert temperature from degrees Fahrenheit to degrees Celsius is $C = \frac{5}{9}(F - 32)$. Graph the equation. At what temperature are degrees Fahrenheit and degrees Celsius equal?

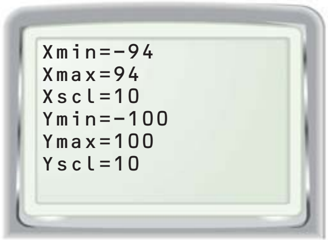
STEP 1 Rewrite and enter equation

Rewrite the equation using x for F and y for C. Enter the equation into the Y= screen. Put parentheses around the fraction $\frac{5}{9}$.



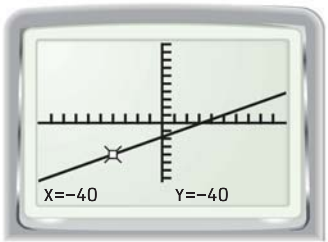
STEP 2 Set window

The screen is a "window" that lets you look at part of a coordinate plane. Press WINDOW to set the borders of the graph. A friendly window for this equation is $-94 \le x \le 94$ and $-100 \le y \le 100$.



STEP 3 Graph and trace equation

Press TRACE and use the left and right arrows to move the cursor along the graph until the x-coordinate and y-coordinate are equal. From the graph, you can see that degrees Fahrenheit and degrees Celsius are equal at -40.



PRACTICE

Graph the equation. Find the unknown value in the ordered pair.

1. $y = 8 - x$; (2.4, ?)
2. $y = 2x + 3$; (?, 0.8)
3. $y = -4.5x + 1$; (1.4, ?)
4. **SPEED OF SOUND** The speed s (in meters per second) of sound in air can be modeled by $s = 331.1 + 0.61T$ where T is the air temperature in degrees Celsius. Graph the equation. Estimate the speed of sound when the temperature is 20°C.

Extension
Use after Lesson 4.2

Identify Discrete and Continuous Functions

GOAL Graph and classify discrete and continuous functions.

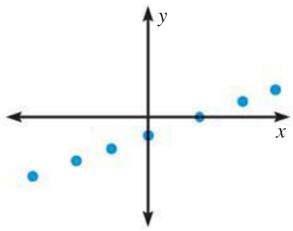
Key Vocabulary
- **discrete function**
- **continuous function**

The graph of a function can consist of individual points, as in the graph in Example 3 on page 207. The graph of a function can also be a line or a part of a line with no breaks, as in the graph in Example 4 on page 217.

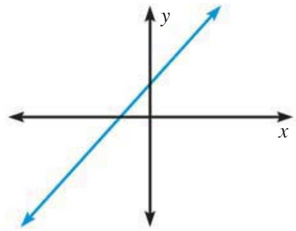
KEY CONCEPT *For Your Notebook*

Identifying Discrete and Continuous Functions

A **discrete function** has a graph that consists of isolated points.



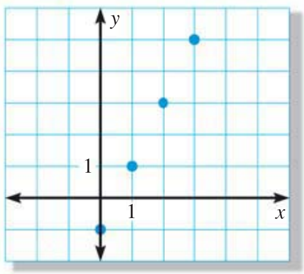
A **continuous function** has a graph that is unbroken.



EXAMPLE 1 Graph and classify a function

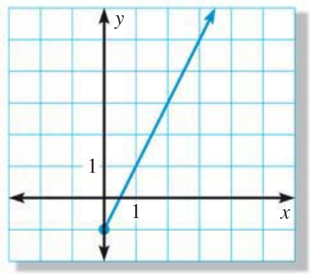
Graph the function $y = 2x - 1$ with the given domain. Classify the function as discrete or continuous.

a. Domain: $x = 0, 1, 2, 3$



The graph consists of individual points, so the function is discrete.

b. Domain: $x \geq 0$



The graph is unbroken, so the function is continuous.

GRAPHS As a general rule, you can tell that a function is continuous if you do not have to lift your pencil from the paper to draw its graph, as in part (b) of Example 1.

EXAMPLE 2 Classify and graph a real-world function

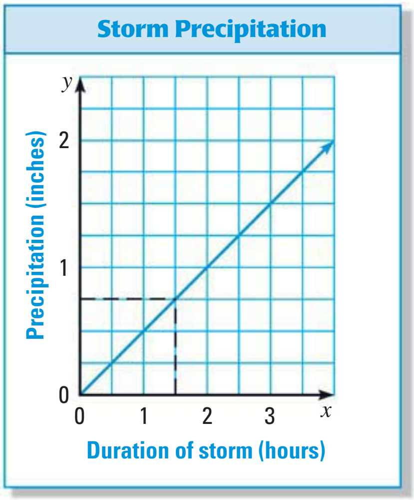
Tell whether the function represented by the table is discrete or continuous. Explain. If continuous, graph the function and find the value of y when $x = 1.5$.

Duration of storm (hours), x	1	2	3
Amount of rain (inches), y	0.5	1	1.5

Solution

Although the table shows the amount of rain that has fallen after whole numbers of hours only, it makes sense to talk about the amount of rain after any amount of time during the storm. So, the table represents a continuous function.

The graph of the function is shown. To find the value of y when $x = 1.5$, start at 1.5 on the x-axis, move up to the graph, and move over to the y-axis. The y-value is about 0.75. So, about 0.75 inch of rain has fallen after 1.5 hours.



PRACTICE

EXAMPLE 1 on p. 223 for Exs. 1–6

Graph the function with the given domain. Classify the function as discrete or continuous.

1. $y = -2x + 3$; domain: $-2, -1, 0, 1, 2$
2. $y = x$; domain: all real numbers
3. $y = -\frac{1}{3}x + 1$; domain: $-12, -6, 0, 6, 12$
4. $y = 0.5x$; domain: $-2, -1, 0, 1, 2$
5. $y = 3x - 4$; domain: $x \le 0$
6. $y = \frac{2}{3}x + \frac{1}{3}$; domain: $x \ge -2$

EXAMPLE 2 on p. 224 for Exs. 7–9

Tell whether the function represented by the table is discrete or continuous. *Explain*. If continuous, graph the function and find the value of y when $x = 3.5$. Round your answer to the nearest hundredth.

7.

Number of DVD rentals, x	1	2	3	4
Cost of rentals (dollars), y	4.50	9.00	13.50	18.00

8.

Hours since 12 P.M., x	2	4	6	8
Distance driven (miles), y	100	200	300	400

9.

Volume of water (cubic inches), x	3	6	9	12
Approximate weight of water (pounds), y	0.1	0.2	0.3	0.4

4.3 Graph Using Intercepts

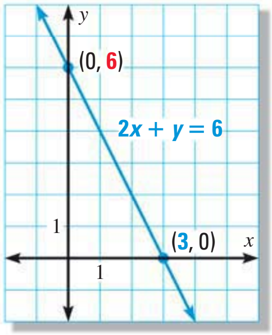
Before You graphed a linear equation using a table of values.

Now You will graph a linear equation using intercepts.

Why So you can find a submersible's location, as in Example 5.

Key Vocabulary
- x-intercept
- y-intercept

You can use the fact that two points determine a line to graph a linear equation. Two convenient points are the points where the graph crosses the axes.



An ***x*-intercept** of a graph is the x-coordinate of a point where the graph crosses the x-axis. A ***y*-intercept** of a graph is the y-coordinate of a point where the graph crosses the y-axis.

To find the x-intercept of the graph of a linear equation, find the value of x when $y = 0$. To find the y-intercept of the graph, find the value of y when $x = 0$.

EXAMPLE 1 Find the intercepts of the graph of an equation

Find the x-intercept and the y-intercept of the graph of $2x + 7y = 28$.

Solution

To find the x-intercept, substitute 0 for y and solve for x.

$2x + 7y = 28$ **Write original equation.**

$2x + 7(0) = 28$ **Substitute 0 for y.**

$x = \frac{28}{2} = 14$ **Solve for x.**

To find the y-intercept, substitute 0 for x and solve for y.

$2x + 7y = 28$ **Write original equation.**

$2(0) + 7y = 28$ **Substitute 0 for x.**

$y = \frac{28}{7} = 4$ **Solve for y.**

▶ The x-intercept is 14. The y-intercept is 4.

✓ GUIDED PRACTICE for Example 1

Find the x-intercept and the y-intercept of the graph of the equation.

1. $3x + 2y = 6$ **2.** $4x - 2y = 10$ **3.** $-3x + 5y = -15$

EXAMPLE 2 Use intercepts to graph an equation

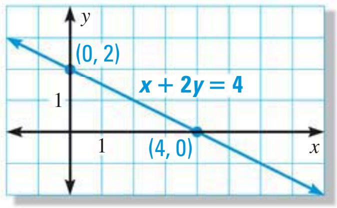
Graph the equation $x + 2y = 4$.

Solution

STEP 1 **Find** the intercepts.

$x + 2y = 4$	$x + 2y = 4$
$x + 2(0) = 4$	$0 + 2y = 4$
$x = 4 \leftarrow$ ***x*-intercept**	$y = 2 \leftarrow$ ***y*-intercept**

STEP 2 **Plot** points. The x-intercept is 4, so plot the point (4, 0). The y-intercept is 2, so plot the point (0, 2). Draw a line through the points.



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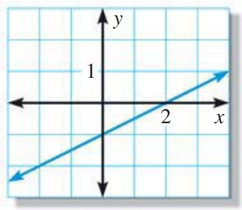
CHECK A GRAPH
Be sure to check the graph by finding a third solution of the equation and checking to see that the corresponding point is on the graph.

EXAMPLE 3 Use a graph to find intercepts

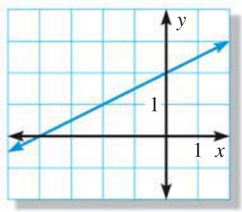
The graph crosses the x-axis at (2, 0). The x-intercept is 2. The graph crosses the y-axis at (0, −1). The y-intercept is −1.



✓ GUIDED PRACTICE for Examples 2 and 3

4. Graph $6x + 7y = 42$. Label the points where the line crosses the axes.

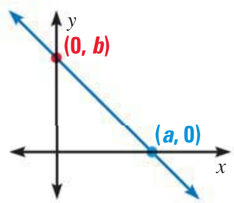
5. Identify the x-intercept and the y-intercept of the graph shown at the right.



KEY CONCEPT *For Your Notebook*

Relating Intercepts, Points, and Graphs

Intercepts	Points
The x intercept of a graph is a.	The graph crosses the x-axis at $(a, 0)$.
The y-intercept of a graph is b.	The graph crosses the y-axis at $(0, b)$.



EXAMPLE 4 Solve a multi-step problem

EVENT PLANNING You are helping to plan an awards banquet for your school, and you need to rent tables to seat 180 people. Tables come in two sizes. Small tables seat 4 people, and large tables seat 6 people. This situation can be modeled by the equation

$$4x + 6y = 180$$

where x is the number of small tables and y is the number of large tables.

- Find the intercepts of the graph of the equation.
- Graph the equation.
- Give four possibilities for the number of each size table you could rent.

Solution

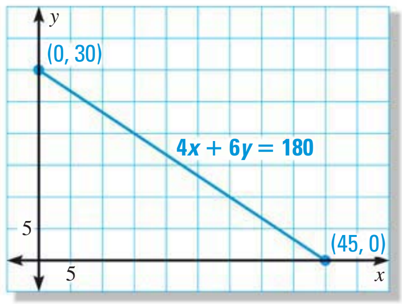
STEP 1 **Find** the intercepts.

$$\begin{aligned} 4x + 6y &= 180 \\ 4x + 6(0) &= 180 \\ x &= 45 \leftarrow \textbf{x-intercept} \end{aligned} \qquad \begin{aligned} 4x + 6y &= 180 \\ 4(0) + 6y &= 180 \\ y &= 30 \leftarrow \textbf{y-intercept} \end{aligned}$$

STEP 2 **Graph** the equation.

The x-intercept is 45, so plot the point (45, 0). The y-intercept is 30, so plot the point (0, 30).

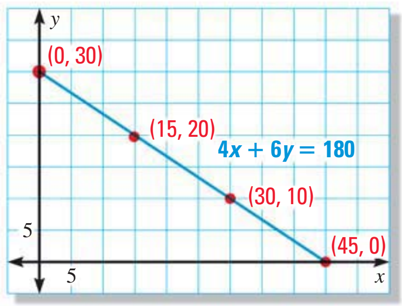
Since x and y both represent numbers of tables, neither x nor y can be negative. So, instead of drawing a line, draw the part of the line that is in Quadrant I.



DRAW A GRAPH
Although x and y represent whole numbers, it is convenient to draw an unbroken line segment that includes points whose coordinates are not whole numbers.

STEP 3 **Find** the number of tables. For this problem, only whole-number values of x and y make sense. You can see that the line passes through the points **(0, 30)**, **(15, 20)**, **(30, 10)**, and **(45, 0)**.

So, four possible combinations of tables that will seat 180 people are: 0 small and 30 large, 15 small and 20 large, 30 small and 10 large, and 45 small and 0 large.

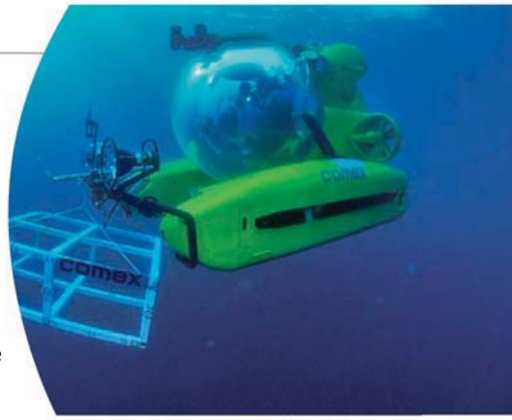


FIND SOLUTIONS
Other points, such as (12, 22), are also on the graph but are not as obvious as the points shown here because their coordinates are not multiples of 5.

✓ GUIDED PRACTICE for Example 4

6. **WHAT IF?** In Example 4, suppose the small tables cost \$9 to rent and the large tables cost \$14. Of the four possible combinations of tables given in the example, which rental is the least expensive? *Explain.*

EXAMPLE 5 Use a linear model



SUBMERSIBLES A submersible designed to explore the ocean floor is at an elevation of −13,000 feet (13,000 feet below sea level). The submersible ascends to the surface at an average rate of 650 feet per minute. The elevation e (in feet) of the submersible is given by the function

$$e = 650t - 13{,}000$$

where t is the time (in minutes) since the submersible began to ascend.

- Find the intercepts of the graph of the function and state what the intercepts represent.
- Graph the function and identify its domain and range.

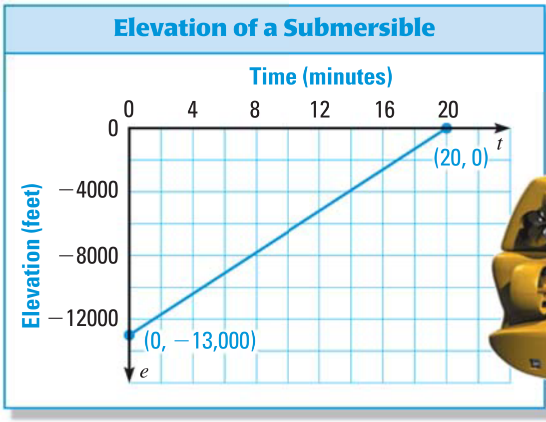
Solution

STEP 1 **Find** the intercepts.

$0 = 650t - 13{,}000$	$e = 650(0) - 13{,}000$
$13{,}000 = 650t$	$e = -13{,}000$ ← ***e*-intercept**
$20 = t$ ← ***t*-intercept**	

The t-intercept represents the number of minutes the submersible takes to reach an elevation of 0 feet (sea level). The e-intercept represents the elevation of the submersible after 0 minutes (the time the ascent begins).

STEP 2 **Graph** the function using the intercepts.



The submersible starts at an elevation of −13,000 feet and ascends to an elevation of 0 feet. So, the range of the function is $-13{,}000 \le e \le 0$. From the graph, you can see that the domain of the function is $0 \le t \le 20$.

NAME INTERCEPTS

Because t is the independent variable, the horizontal axis is the t-axis, and you refer to the "t-intercept" of the graph of the function. Similarly, the vertical axis is the e-axis, and you refer to the "e-intercept."

✓ GUIDED PRACTICE for Example 5

7. **WHAT IF?** In Example 5, suppose the elevation of a second submersible is given by $e = 500t - 10{,}000$. Graph the function and identify its domain and range.

4.3 EXERCISES

HOMEWORK KEY

○ = **WORKED-OUT SOLUTIONS** on p. WS1 for Exs. 21 and 47

★ = **STANDARDIZED TEST PRACTICE** Exs. 2, 37, 41, 49, and 50

◆ = **MULTIPLE REPRESENTATIONS** Ex. 44

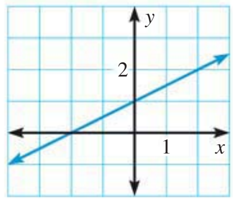
SKILL PRACTICE

1. **VOCABULARY** Copy and complete: The _?_ of the graph of an equation is the value of x when y is zero.

2. ★ **WRITING** What are the x-intercept and the y-intercept of the line passing through the points $(0, 3)$ and $(-4, 0)$? *Explain*.

3. **ERROR ANALYSIS** *Describe* and correct the error in finding the intercepts of the line shown.

The x-intercept is 1,
and the y-intercept is −2.



EXAMPLE 1
on p. 225
for Exs. 4–15

FINDING INTERCEPTS **Find the x-intercept and the y-intercept of the graph of the equation.**

4. $5x - y = 35$
5. $3x - 3y = 9$
6. $-3x + 9y = -18$
7. $4x + y = 4$
8. $2x + y = 10$
9. $2x - 8y = 24$
10. $3x + 0.5y = 6$
11. $0.2x + 3.2y = 12.8$
12. $y = 2x + 24$
13. $y = -14x + 7$
14. $y = -4.8x + 1.2$
15. $y = \frac{3}{5}x - 12$

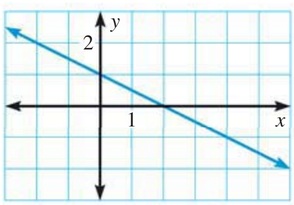
EXAMPLE 2
on p. 226
for Exs. 16–27

GRAPHING LINES **Graph the equation. Label the points where the line crosses the axes.**

16. $y = x + 3$
17. $y = x - 2$
18. $y = 4x - 8$
19. $y = 5 + 10x$
20. $y = -2 + 8x$
21. $y = -4x + 3$
22. $3x + y = 15$
23. $x - 4y = 18$
24. $8x - 5y = 80$
25. $-2x + 5y = 15$
26. $0.5x + 3y = 9$
27. $y = \frac{1}{2}x + \frac{1}{4}$

EXAMPLE 3
on p. 226
for Exs. 28–30

USING GRAPHS TO FIND INTERCEPTS **Identify the x-intercept and the y-intercept of the graph.**

28.


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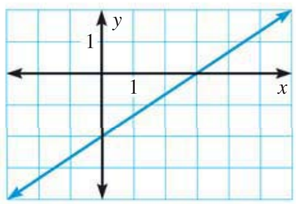
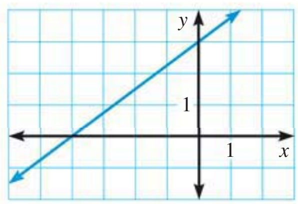


30.


USING INTERCEPTS **Draw the line that has the given intercepts.**

31. x-intercept: 3
y-intercept: 5

32. x-intercept: -2
y-intercept: 4

33. x-intercept: -5
y-intercept: 6

34. x-intercept: 9
y-intercept: -1

35. x-intercept: -8
y-intercept: -11

36. x-intercept: -2
y-intercept: -6

37. ★ **MULTIPLE CHOICE** The x-intercept of the graph of $Ax + 5y = 20$ is 2. What is the value of A?

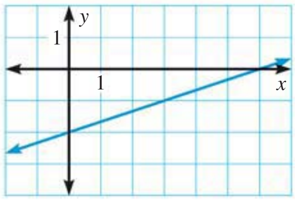
Ⓐ 2 Ⓑ 5 Ⓒ 7.5 Ⓓ 10

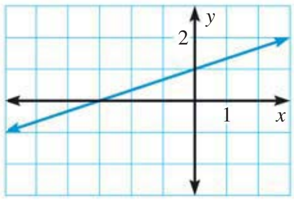
MATCHING EQUATIONS WITH GRAPHS **Match the equation with its graph.**

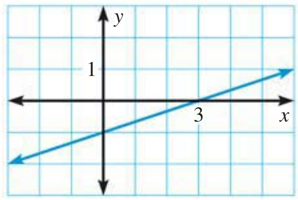
38. $2x - 6y = 6$

39. $2x - 6y = -6$

40. $2x - 6y = 12$

A.


B.


C.


41. ★ **WRITING** Is it possible for a line *not* to have an x-intercept? Is it possible for a line *not* to have a y-intercept? *Explain.*

42. **REASONING** Consider the equation $3x + 5y = k$. What values could k have so that the x-intercept and the y-intercept of the equation's graph would both be integers? *Explain.*

43. **CHALLENGE** If $a \neq 0$, find the intercepts of the graph of $y = ax + b$ in terms of a and b.

PROBLEM SOLVING

EXAMPLES 4 and 5 on pp. 227–228 for Exs. 44–47

44. **MULTIPLE REPRESENTATIONS** The perimeter of a rectangular park is 72 feet. Let x be the park's width (in feet) and let y be its length (in feet).

a. **Writing an Equation** Write an equation for the perimeter.

b. **Drawing a Graph** Find the intercepts of the graph of the equation you wrote. Then graph the equation.

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45. **RECYCLING** In one state, small bottles have a refund value of \$.04 each, and large bottles have a refund value of \$.08 each. Your friend returns both small and large bottles and receives \$.56. This situation is given by $4x + 8y = 56$ where x is the number of small bottles and y is the number of large bottles.

a. Find the intercepts of the graph of the equation. Graph the equation.

b. Give three possibilities for the number of each size bottle your friend could have returned.

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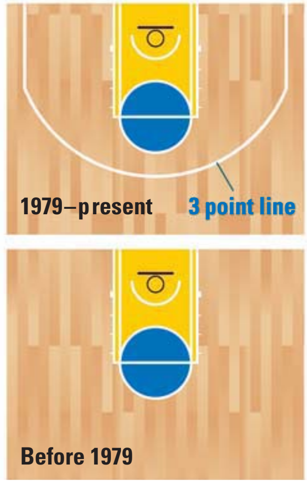
46. **MULTI-STEP PROBLEM** Before 1979, there was no 3-point shot in professional basketball; players could score only 2-point field goals and 1-point free throws. In a game before 1979, a team scored a total of 128 points. This situation is given by the equation $2x + y = 128$ where x is the possible number of field goals and y is the possible number of free throws.



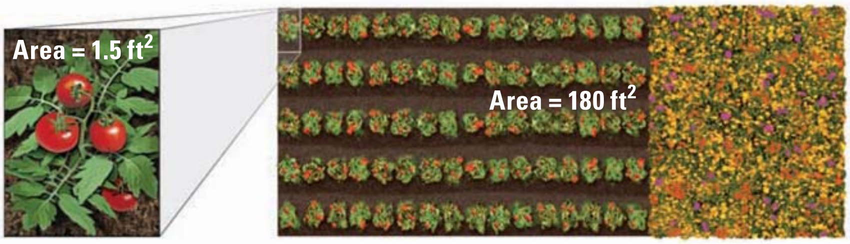
a. Find the intercepts of the graph of the equation. Graph the equation.

b. What do the intercepts mean in this situation?

c. What are three possible numbers of field goals and free throws the team could have scored?

d. If the team made 24 free throws, how many field goals were made?

47. **COMMUNITY GARDENS** A family has a plot in a community garden. The family is going to plant vegetables, flowers, or both. The diagram shows the area used by one vegetable plant and the area of the entire plot. The area f (in square feet) of the plot left for flowers is given by $f = 180 - 1.5v$ where v is the number of vegetable plants the family plants.



a. Find the intercepts of the graph of the function and state what the intercepts represent.

b. Graph the function and identify its domain and range.

c. The family decides to plant 80 vegetable plants. How many square feet are left to plant flowers?

48. **CAR SHARING** A member of a car-sharing program can use a car for \$6 per hour and \$.50 per mile. The member uses the car for one day and is charged \$44. This situation is given by

$$6t + 0.5d = 44$$

where t is the time (in hours) the car is used and d is the distance (in miles) the car is driven. Give three examples of the number of hours the member could have used the car and the number of miles the member could have driven the car.

49. ★ **SHORT RESPONSE** A humidifier is a device used to put moisture into the air by turning water to vapor. A humidifier has a tank that can hold 1.5 gallons of water. The humidifier can disperse the water at a rate of 0.12 gallon per hour. The amount of water w (in gallons) left in the humidifier after t hours of use is given by the function

$$w = 1.5 - 0.12t.$$

After how many hours of use will you have to refill the humidifier? *Explain* how you found your answer.

50. ★ **EXTENDED RESPONSE** You borrow \$180 from a friend who doesn't charge you interest. You work out a payment schedule in which you will make weekly payments to your friend. The balance B (in dollars) of the loan is given by the function $B = 180 - pn$ where p is the weekly payment and n is the number of weeks you make payments.

a. **Interpret** Without finding the intercepts, state what they represent.

b. **Graph** Graph the function if you make weekly payments of \$20.

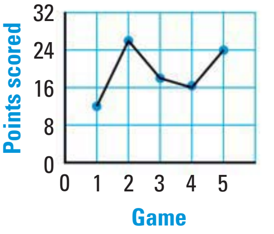
c. **Identify** Find the domain and range of the function in part (b). How long will it take to pay back your friend?

d. **CHALLENGE** Suppose you make payments of \$20 for three weeks. Then you make payments of \$15 until you have paid your friend back. How does this affect the graph? How many payments do you make?

MIXED REVIEW

REVIEW GRAPHS
For help with line graphs, see p. 934.

In Exercises 51–53, use the line graph, which shows the number of points Alex scored in five basketball games. *(p. 934)*



51. How many points did Alex score in game 4?

52. In which game did Alex score the most points?

53. How many more points did Alex score in game 5 than in game 1?

PREVIEW
Prepare for Lesson 4.4 in Exs. 54–56.

Solve the proportion. *(p. 934)*

54. $\frac{3}{5} = \frac{x}{30}$

55. $\frac{x}{x + 6} = \frac{7}{6}$

56. $\frac{t - 3}{12} = \frac{2t - 2}{9}$

QUIZ *for Lessons 4.1–4.3*

Plot the point in a coordinate plane. *Describe* the location of the point. *(p. 206)*

1. $(-7, 2)$
2. $(0, -5)$
3. $(2, -6)$

Graph the equation. *(p. 215)*

4. $-4x - 2y = 12$
5. $y = -5$
6. $x = 6$

Find the x-intercept and the y-intercept of the graph of the equation. *(p. 225)*

7. $y = x + 7$
8. $y = x - 3$
9. $y = -5x + 2$
10. $x + 3y = 15$
11. $3x - 6y = 36$
12. $-2x - 5y = 22$

13. **SWIMMING POOLS** A public swimming pool that holds 45,000 gallons of water is going to be drained for maintenance at a rate of 100 gallons per minute. The amount of water w (in gallons) in the pool after t minutes is given by the function $w = 45{,}000 - 100t$. Graph the function. Identify its domain and range. How much water is in the pool after 60 minutes? How many minutes will it take to empty the pool? *(p. 225)*

MIXED REVIEW of Problem Solving

STATE TEST PRACTICE
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Lessons 4.1–4.3

1. **MULTI-STEP PROBLEM** An amusement park charges \$20 for an all-day pass and \$10 for a pass after 5 P.M. On Wednesday the amusement park collected \$1000 in pass sales. This situation can be modeled by the equation $1000 = 20x + 10y$ where x is the number of all-day passes sold and y is the number of passes sold after 5 P.M.

   a. Find the x-intercept of the graph of the equation. What does it represent?

   b. Find the y-intercept of the graph of the equation. What does it represent?

   c. Graph the equation using a scale of 10 on the x- and y-axes.

2. **MULTI-STEP PROBLEM** A violin player who plays every day received a violin with new strings. Players who play every day should replace the strings on their violins every 6 months. A particular brand of strings costs \$24 per pack. The table shows the total spent a (in dollars) on replacement strings with respect to time t (in months).

t (months)	a (dollars)
6	24
12	48
18	72
24	96
30	120

   a. *Explain* how you know the table represents a function.

   b. Graph the function.

3. **OPEN-ENDED** Create a table that shows the number of minutes you think you will spend watching TV next week. Let Monday be day 1, Tuesday be day 2, and so on. Graph the data. Does the graph represent a function? *Explain*.

4. **SHORT RESPONSE** You can hike at an average rate of 3 miles per hour. Your total hiking distance d (in miles) can be modeled by the function $d = 3t$ where t is the time (in hours) you hike. You plan on hiking for 10 hours this weekend.

   a. Is the domain or range specified in the problem? *Explain*.

   b. Graph the function and identify its domain and range. Use the graph to find how long it takes to hike 6 miles.

5. **EXTENDED RESPONSE** The table shows the departure d (in degrees Fahrenheit) from the normal monthly temperature in New England for the first six months of 2004. For example, in month 1, $d = -3$. So, the average temperature was 3 degrees below the normal temperature for January.

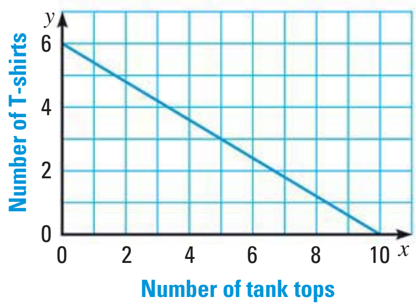
M (month)	1	2	3	4	5	6
d (°F)	−3	−1	2	2	4	−1

   a. *Explain* how you know the table represents a function.

   b. Graph the function and identify its domain and range.

   c. What does a point in Quadrant IV mean in terms of this situation?

6. **GRIDDED ANSWER** The graph shows the possible combinations of T-shirts and tank tops that you can buy with the amount of money you have. If you buy only T-shirts, how many can you buy?



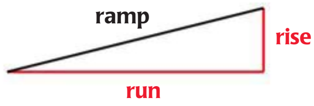
4.4 Slopes of Lines

MATERIALS • several books • two rulers

QUESTION How can you use algebra to describe the slope of a ramp?

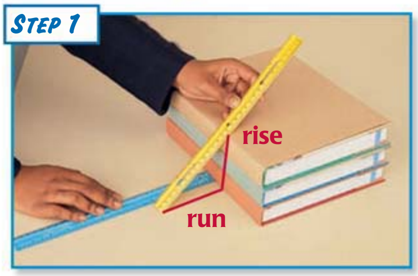
You can use the ratio of the vertical rise to the horizontal run to describe the *slope* of a ramp.

$$\text{slope} = \frac{\text{rise}}{\text{run}}$$

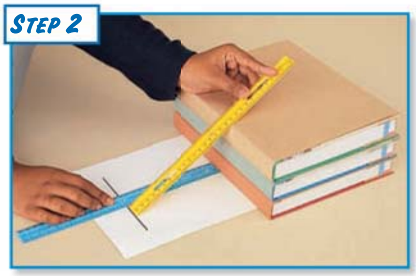


EXPLORE Calculate the slopes of ramps

STEP 1



STEP 2



STEP 3

Make a ramp Make a stack of three books. Use a ruler as a ramp. Measure the rise and run of the ramp, and record them in a table. Calculate and record the slope of the ramp in your table.

Change the run Without changing the rise, make three ramps with different runs by moving the lower end of the ruler. Measure and record the rise and run of each ramp. Calculate and record each slope.

Change the rise Without changing the run, make three ramps with different rises by adding or removing books. Measure and record the rise and run of each ramp. Calculate and record each slope.

DRAW CONCLUSIONS Use your observations to complete these exercises

Describe **how the slope of the ramp changes given the following conditions. Give three examples that support your answer.**

1. The run of the ramp increases, and the rise stays the same.
2. The rise of the ramp increases, and the run stays the same.

In Exercises 3–5, describe the relationship between the rise and the run of the ramp.

3. A ramp with a slope of 1
4. A ramp with a slope greater than 1
5. A ramp with a slope less than 1
6. Ramp A has a rise of 6 feet and a run of 2 feet. Ramp B has a rise of 10 feet and a run of 4 feet. Which ramp is steeper? How do you know?

4.4 Find Slope and Rate of Change

Before	You graphed linear equations.
Now	You will find the slope of a line and interpret slope as a rate of change.
Why?	So you can find the slope of a boat ramp, as in Ex. 23.

Key Vocabulary
- **slope**
- **rate of change**

The **slope** of a nonvertical line is the ratio of the vertical change (the *rise*) to the horizontal change (the *run*) between any two points on the line. The slope of a line is represented by the letter m.

KEY CONCEPT *For Your Notebook*

Finding the Slope of a Line

Words

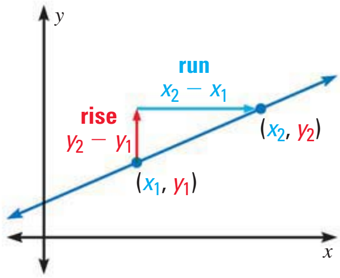
The slope m of the nonvertical line passing through the two points (x_1, y_1) and (x_2, y_2) is the ratio of the rise (change in y) to the run (change in x).

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{\text{change in } y}{\text{change in } x}$$

Symbols

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

Graph



READING

Read x_1 as "x sub one." Think "x-coordinate of the first point." Read y_1 as "y sub one." Think "y-coordinate of the first point."

EXAMPLE 1 Find a positive slope

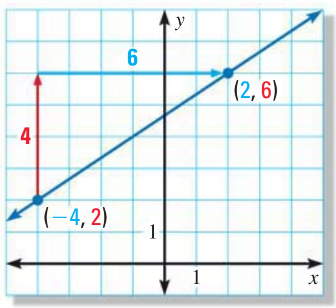
Find the slope of the line shown.

Let $(x_1, y_1) = (-4, 2)$ and $(x_2, y_2) = (2, 6)$.

$m = \dfrac{y_2 - y_1}{x_2 - x_1}$ **Write formula for slope.**

$= \dfrac{6 - 2}{2 - (-4)}$ **Substitute.**

$= \dfrac{4}{6} = \dfrac{2}{3}$ **Simplify.**



The line rises from left to right. The slope is positive.

AVOID ERRORS

Be sure to keep the x- and y-coordinates in the same order in both the numerator and denominator when calculating slope.

✓ GUIDED PRACTICE for Example 1

Find the slope of the line that passes through the points.

1. $(5, 2)$ and $(4, -1)$ **2.** $(-2, 3)$ and $(4, 6)$ **3.** $\left(\frac{9}{2}, 5\right)$ and $\left(\frac{1}{2}, -3\right)$

EXAMPLE 2 Find a negative slope

FIND SLOPE
In Example 2, if you used two other points on the line, such as (4, 3) and (5, 1), in the slope formula, the slope would still be −2.

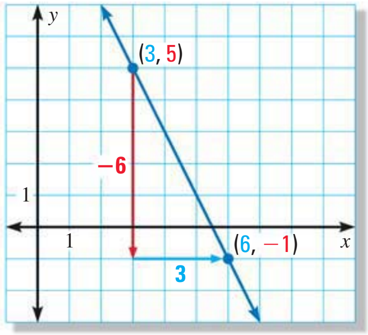
Find the slope of the line shown.

Let $(x_1, y_1) = (3, 5)$ and $(x_2, y_2) = (6, -1)$.

$m = \frac{y_2 - y_1}{x_2 - x_1}$ **Write formula for slope.**

$= \frac{-1 - 5}{6 - 3}$ **Substitute.**

$= \frac{-6}{3} = -2$ **Simplify.**



The line falls from left to right. The slope is negative.

EXAMPLE 3 Find the slope of a horizontal line

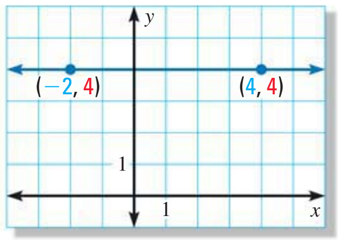
Find the slope of the line shown.

Let $(x_1, y_1) = (-2, 4)$ and $(x_2, y_2) = (4, 4)$.

$m = \frac{y_2 - y_1}{x_2 - x_1}$ **Write formula for slope.**

$= \frac{4 - 4}{4 - (-2)}$ **Substitute.**

$= \frac{0}{6} = 0$ **Simplify.**



The line is horizontal. The slope is zero.

EXAMPLE 4 Find the slope of a vertical line

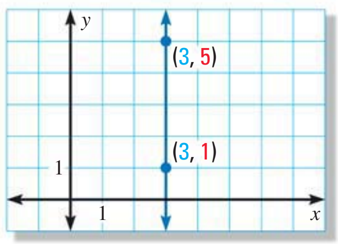
Find the slope of the line shown.

Let $(x_1, y_1) = (3, 5)$ and $(x_2, y_2) = (3, 1)$.

$m = \frac{y_2 - y_1}{x_2 - x_1}$ **Write formula for slope.**

$= \frac{1 - 5}{3 - 3}$ **Substitute.**

$= \cancel{\frac{-4}{0}}$ **Division by zero is undefined.**



The line is vertical. The slope is undefined.

▶ Because division by zero is undefined, the slope of a vertical line is undefined.

✓ GUIDED PRACTICE for Examples 2, 3, and 4

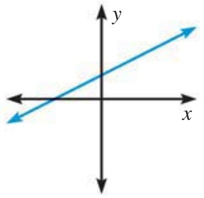
Find the slope of the line that passes through the points.

4. (5, 2) and (5, −2) **5.** (0, 4) and (−3, 4) **6.** (0, 6) and (5, −4)

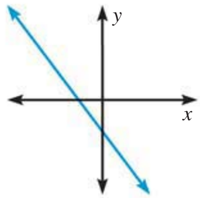
CONCEPT SUMMARY — *For Your Notebook*

Classification of Lines by Slope

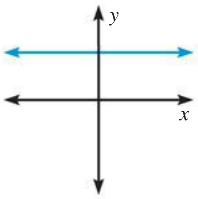
A line with positive slope ($m > 0$) *rises* from left to right.



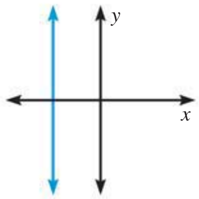
A line with negative slope ($m < 0$) *falls* from left to right.



A line with zero slope ($m = 0$) is *horizontal*.



A line with undefined slope is *vertical*.



RATE OF CHANGE A **rate of change** compares a change in one quantity to a change in another quantity. For example, if you are paid \$60 for working 5 hours, then your hourly wage is \$12 per hour, a rate of change that describes how your pay increases with respect to time spent working.

EXAMPLE 5 Find a rate of change

INTERNET CAFE The table shows the cost of using a computer at an Internet cafe for a given amount of time. Find the rate of change in cost with respect to time.

Time (hours)	2	4	6
Cost (dollars)	7	14	21

Solution

$$\text{Rate of change} = \frac{\text{change in cost}}{\text{change in time}}$$

$$= \frac{14 - 7}{4 - 2} = \frac{7}{2} = 3.5$$

▶ The rate of change in cost is \$3.50 per hour.

ANALYZE UNITS
Because the cost is in dollars and time is in hours, the rate of change in cost with respect to time is expressed in dollars per hour.

✓ GUIDED PRACTICE for Example 5

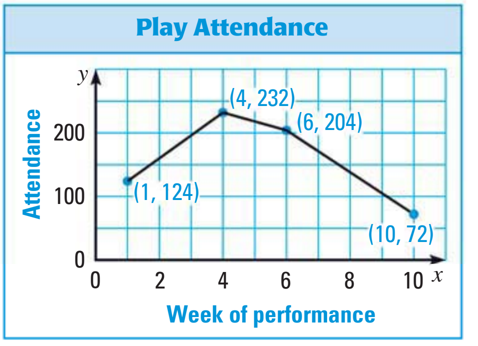
7. **EXERCISE** The table shows the distance a person walks for exercise. Find the rate of change in distance with respect to time.

Time (minutes)	Distance (miles)
30	1.5
60	3
90	4.5

SLOPE AND RATE OF CHANGE You can interpret the slope of a line as a rate of change. When given graphs of real-world data, you can compare rates of change by comparing slopes of lines.

EXAMPLE 6 Use a graph to find and compare rates of change

COMMUNITY THEATER A community theater performed a play each Saturday evening for 10 consecutive weeks. The graph shows the attendance for the performances in weeks 1, 4, 6, and 10. Describe the rates of change in attendance with respect to time.



Solution

Find the rates of change using the slope formula.

INTERPRET RATE OF CHANGE
A negative rate of change indicates a decrease.

Weeks 1–4: $\frac{232 - 124}{4 - 1} = \frac{108}{3} = 36$ people per week

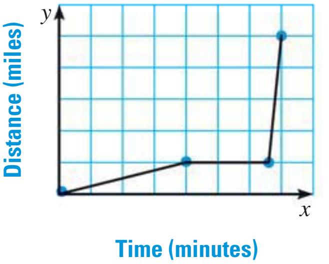
Weeks 4–6: $\frac{204 - 232}{6 - 4} = \frac{-28}{2} = -14$ people per week

Weeks 6–10: $\frac{72 - 204}{10 - 6} = \frac{-132}{4} = -33$ people per week

▶ Attendance increased during the early weeks of performing the play. Then attendance decreased, slowly at first, then more rapidly.

EXAMPLE 7 Interpret a graph

COMMUTING TO SCHOOL A student commutes from home to school by walking and by riding a bus. Describe the student's commute in words.



Solution

The first segment of the graph is not very steep, so the student is not traveling very far with respect to time. The student must be walking. The second segment has a zero slope, so the student must not be moving. He or she is waiting for the bus. The last segment is steep, so the student is traveling far with respect to time. The student must be riding the bus.

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✓ GUIDED PRACTICE for Examples 6 and 7

8. **WHAT IF?** How would the answer to Example 6 change if you knew that attendance was 70 people in week 12?

9. **WHAT IF?** Using the graph in Example 7, draw a graph that represents the student's commute from school to home.

4.4 EXERCISES

HOMEWORK KEY

○ = **WORKED-OUT SOLUTIONS** on p. WS1 for Exs. 11 and 37

★ = **STANDARDIZED TEST PRACTICE** Exs. 2, 17, 18, 34, and 40

SKILL PRACTICE

1. **VOCABULARY** Copy and complete: The __?__ of a nonvertical line is the ratio of the vertical change to the horizontal change between any two points on the line.

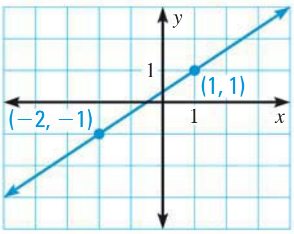
2. ★ **WRITING** Without calculating the slope, how can you tell that the slope of the line that passes through the points (−5, −3) and (2, 4) is positive?

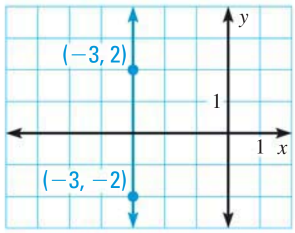
3. **ERROR ANALYSIS** *Describe* and correct the error in calculating the slope of the line passing through the points (5, 3) and (2, 6).

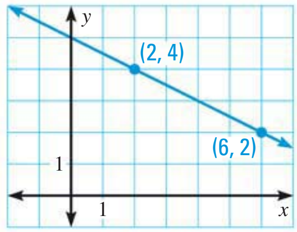
$$m = \frac{6-3}{5-2} = \frac{3}{3} = 1$$

EXAMPLES 1,2,3, and 4 on pp. 235–236 for Exs. 4–18

FINDING SLOPE **Tell whether the slope of the line is *positive*, *negative*, *zero*, or *undefined*. Then find the slope if it exists.**

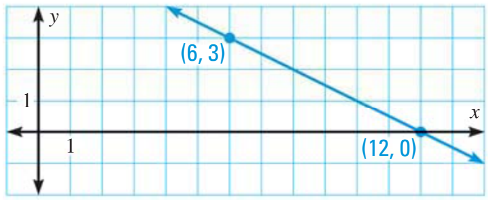
4. 

5. 

6. 

7. **ERROR ANALYSIS** *Describe* and correct the error in calculating the slope of the line shown.

$$m = \frac{12-6}{0-3} = \frac{6}{-3} = -2$$



FINDING SLOPE **Find the slope of the line that passes through the points.**

8. (−2, −1) and (4, 5)
9. (−3, −2) and (−3, 6)
10. (5, −3) and (−5, −3)
11. (1, 3) and (3, −2)
12. (−3, 4) and (4, 1)
13. (1, −3) and (7, 3)
14. (0, 0) and (0, −6)
15. (−9, 1) and (1, 1)
16. (−10, −2) and (−8, 8)

17. ★ **MULTIPLE CHOICE** The slope of the line that passes through the points (−2, −3) and (8, −3) is __?__.

Ⓐ positive Ⓑ negative Ⓒ zero Ⓓ undefined

18. ★ **MULTIPLE CHOICE** What is the slope of the line that passes through the points (7, −9) and (−13, −6)?

Ⓐ $-\frac{3}{20}$ Ⓑ $\frac{3}{20}$ Ⓒ $\frac{3}{4}$ Ⓓ $\frac{5}{2}$

EXAMPLE 5
on p. 237
for Exs. 19–20

19. **MOVIE RENTALS** The table shows the number of days you keep a rented movie before returning it and the total cost of renting the movie. Find the rate of change in cost with respect to time and interpret its meaning.

Time (days)	4	5	6	7
Total cost (dollars)	6.00	8.25	10.50	12.75

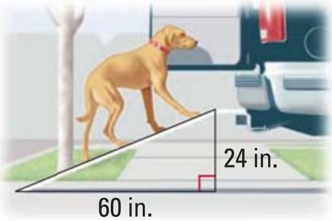
20. **AMUSEMENT PARK** The table shows the amount of time spent at an amusement park and the admission fee the park charges. Find the rate of change in the fee with respect to time spent at the park and interpret its meaning.

Time (hours)	4	5	6
Admission fee (dollars)	34.99	34.99	34.99

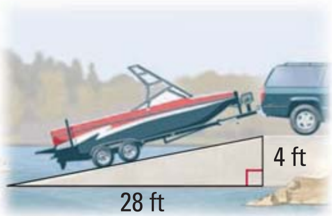
FINDING SLOPE **Find the slope of the object. Round to the nearest tenth.**

21. Skateboard ramp

22. Pet ramp



23. Boat ramp



In Exercises 24–32, use the example below to find the value of *x* or *y* so that the line passing through the given points has the given slope.

EXAMPLE **Find a coordinate given the slope of a line**

Find the value of x so that the line that passes through the points $(2, 3)$ and $(x, 9)$ has a slope of $\frac{3}{2}$.

Solution

Let $(x_1, y_1) = (2, 3)$ and $(x_2, y_2) = (x, 9)$.

$m = \frac{y_2 - y_1}{x_2 - x_1}$ **Write formula for slope.**

$\frac{3}{2} = \frac{9 - 3}{x - 2}$ **Substitute values.**

$3(x - 2) = 2(9 - 3)$ **Cross products property**

$3x - 6 = 12$ **Simplify.**

$x = 6$ **Solve for *x*.**

24. $(x, 4), (6, -1); m = \frac{5}{6}$

25. $(0, y), (-2, 1); m = -8$

26. $(8, 1), (x, 7); m = -\frac{1}{2}$

27. $(5, 4), (-5, y); m = \frac{3}{5}$

28. $(-9, y), (0, -3); m = -\frac{7}{9}$

29. $(x, 9), (-1, 19); m = 5$

30. $(9, 3), (-6, 7y); m = 3$

31. $(-3, y + 1), (0, 4); m = 6$

32. $\left(\frac{x}{2}, 7\right), (-10, 15); m = 4$

○ = WORKED-OUT SOLUTIONS on p. WS1

★ = STANDARDIZED TEST PRACTICE

33. **REASONING** The point $(-1, 8)$ is on a line that has a slope of -3. Is the point $(4, -7)$ on the same line? *Explain* your reasoning.

34. ★ **WRITING** Is a line with undefined slope the graph of a function? *Explain*.

35. **CHALLENGE** Given two points (x_1, y_1) and (x_2, y_2) such that $x_1 \neq x_2$, show that $\frac{y_2 - y_1}{x_2 - x_1} = \frac{y_1 - y_2}{x_1 - x_2}$. What does this result tell you about calculating the slope of a line?

PROBLEM SOLVING

EXAMPLE 6 on p. 238 for Exs. 36–37

36. **OCEANOGRAPHY** Ocean water levels are measured hourly at a monitoring station. The table shows the water level (in meters) on one particular morning. *Describe* the rates of change in water levels throughout the morning.

Hours since 12:00 A.M.	1	3	8	10	12
Water level (meters)	2	1.4	0.5	1	1.8

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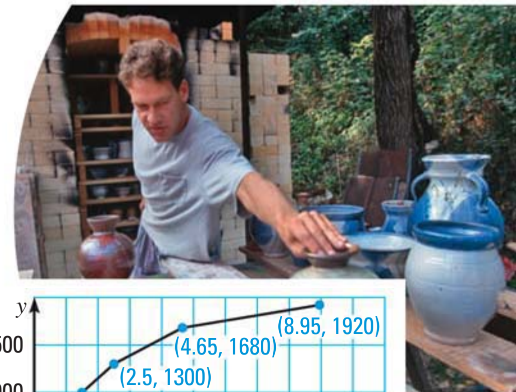
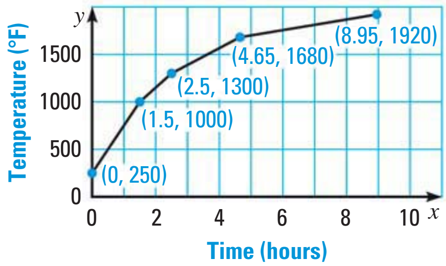
37. **MULTI-STEP PROBLEM** Firing a piece of pottery in a kiln takes place at different temperatures for different amounts of time. The graph shows the temperatures in a kiln while firing a piece of pottery (after the kiln is preheated to 250°F).





a. Determine the time interval during which the temperature in the kiln showed the greatest rate of change.

b. Determine the time interval during which the temperature in the kiln showed the least rate of change.

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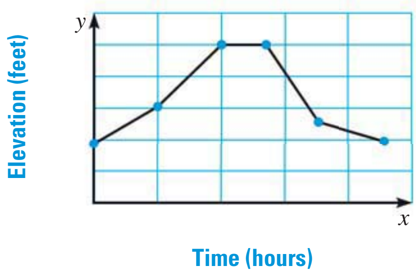
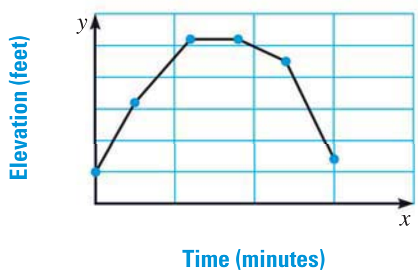
EXAMPLE 7 on p. 238 for Exs. 38–39

38. **FLYING** The graph shows the altitude of a plane during 4 hours of a flight. Give a verbal description of the flight.



39. **HIKING** The graph shows the elevation of a hiker walking on a mountain trail. Give a verbal description of the hike.

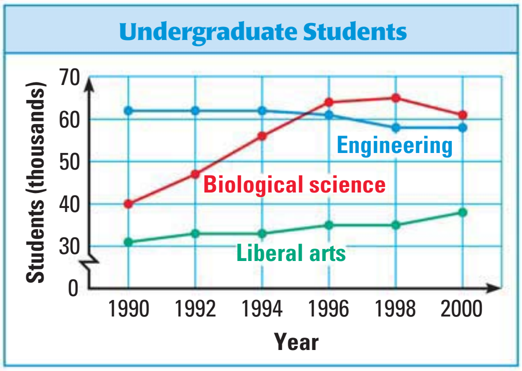


40. ★ **EXTENDED RESPONSE** The graph shows the number (in thousands) of undergraduate students who majored in biological science, engineering, or liberal arts in the United States from 1990 to 2000.

a. During which two-year period did the number of engineering students decrease the most? Estimate the rate of change for this time period.

b. During which two-year period did the number of liberal arts students increase the most? Estimate the rate of change for this time period.

c. How did the total number of students majoring in biological science, engineering, and liberal arts change in the 10 year period? *Explain* your thinking.



41. **CHALLENGE** Imagine the containers below being filled with water at a constant rate. Sketch a graph that shows the water level for each container during the time it takes to fill the container with water.

a.

b.

c.

MIXED REVIEW

Check whether the given number is a solution of the equation or inequality. *(p. 21)*

42. $4b - 7 = b + 11; 6$ **43.** $x - 8 = -2x - 14; -1$ **44.** $\frac{t}{4} + 9 = 13; 16$

45. $a + 9 > 20; 3$ **46.** $\frac{y+3}{2} < 13; 23$ **47.** $2(p + 5) \leq 75; 4$

Evaluate the expression. Approximate the square root to the nearest integer, if necessary. *(p. 110)*

48. $\sqrt{16}$ **49.** $-\sqrt{9}$ **50.** $\pm\sqrt{45}$

51. $\sqrt{136}$ **52.** $\pm\sqrt{64}$ **53.** $-\sqrt{33}$

54. $\pm\sqrt{154}$ **55.** $\pm\sqrt{256}$ **56.** $\sqrt{4761}$

PREVIEW
Prepare for Lesson 4.5 in Exs. 57–62.

Find the *x*-intercept and the *y*-intercept of the graph of the equation. *(p. 225)*

57. $y = x + 7$ **58.** $y = -x - 1$ **59.** $y = 8 - 2x$

60. $y = 3x + 5$ **61.** $y = 4x - 10$ **62.** $y = -9 + 6x$

4.5 Slope and y-Intercept

QUESTION How can you use the equation of a line to find its slope and y-intercept?

EXPLORE Find the slopes and the y-intercepts of lines

STEP 1 *Find y when x = 0*
Copy the table below. Let $x_1 = 0$ and find y_1 for each equation. Use your answers to complete the second and fifth columns in the table.

STEP 2 *Find y when x = 2*
Let $x_2 = 2$ and find y_2 for each equation. Use your answers to complete the third column in the table.

STEP 3 *Compute the slope*
Use the slope formula and the ordered pairs you found in the second and third columns to complete the fourth column.

Line	$(0, y_1)$	$(2, y_2)$	Slope	y-intercept
$y = 4x + 3$	(0, 3)	(2, 11)	$\frac{11-3}{2-0} = 4$	3
$y = -2x + 3$	(0, ?)	(2, ?)	?	?
$y = \frac{1}{2}x + 4$	(0, ?)	(2, ?)	?	?
$y = -4x - 3$	(0, ?)	(2, ?)	?	?
$y = -\frac{1}{4}x - 3$	(0, ?)	(2, ?)	?	?

DRAW CONCLUSIONS Use your observations to complete these exercises

1. *Compare* the slope of each line with the equation of the line. What do you notice?
2. *Compare* the y-intercept of each line with the equation of the line. What do you notice?

Predict the slope and the y-intercept of the line with the given equation. Then check your predictions by finding the slope and y-intercept as you did in the table above.

3. $y = -5x + 1$
4. $y = \frac{3}{4}x + 2$
5. $y = -\frac{3}{2}x - 1$

6. **REASONING** Use the procedure you followed to complete the table above to show that the y-intercept of the graph of $y = mx + b$ is b and the slope of the graph is m.

4.5 Graph Using Slope-Intercept Form

Before You found slopes and graphed equations using intercepts.

Now You will graph linear equations using slope-intercept form.

Why? So you can model a worker's earnings, as in Ex. 43.

Key Vocabulary
- **slope-intercept form**
- **parallel**

In the activity on page 243, you saw how the slope and y-intercept of the graph of a linear equation in the form $y = mx + b$ are related to the equation.

KEY CONCEPT *For Your Notebook*

Finding the Slope and y-Intercept of a Line

Words

A linear equation of the form $y = mx + b$ is written in **slope-intercept form** where m is the slope and b is the y-intercept of the equation's graph.

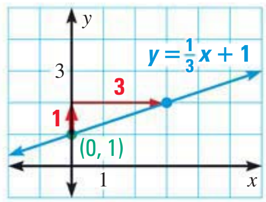
Symbols

$y = mx + b$

slope $\quad$ y-intercept

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

Graph



EXAMPLE 1 Identify slope and y-intercept

Identify the slope and y-intercept of the line with the given equation.

a. $y = 3x + 4$ $\qquad$ **b.** $3x + y = 2$

Solution

a. The equation is in the form $y = mx + b$. So, the slope of the line is 3, and the y-intercept is 4.

b. Rewrite the equation in slope-intercept form by solving for y.

$3x + y = 2$ $\quad$ Write original equation.

$y = -3x + 2$ $\quad$ Subtract $3x$ from each side.

▶ The line has a slope of -3 and a y-intercept of 2.

REWRITE EQUATIONS
When you rewrite a linear equation in slope-intercept form, you are expressing y as a function of x.

GUIDED PRACTICE for Example 1

Identify the slope and y-intercept of the line with the given equation.

1. $y = 5x - 3$ $\qquad$ **2.** $3x - 3y = 12$ $\qquad$ **3.** $x + 4y = 6$

EXAMPLE 2 Graph an equation using slope-intercept form

Graph the equation $2x + y = 3$.

Solution

STEP 1 **Rewrite** the equation in slope-intercept form.

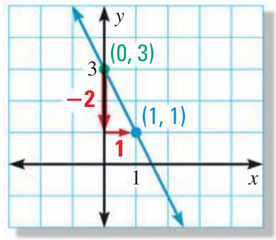
$y = -2x + 3$

STEP 2 **Identify** the slope and the y-intercept.

$m = -2$ and $b = 3$

STEP 3 **Plot** the point that corresponds to the y-intercept, $(0, 3)$.

STEP 4 **Use** the slope to locate a second point on the line. Draw a line through the two points.



CHECK REASONABLENESS
To check the line drawn in Example 2, substitute the coordinates of the second point into the original equation. You should get a true statement.

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MODELING In real-world problems that can be modeled by linear equations, the y-intercept is often an initial value, and the slope is a rate of change.

EXAMPLE 3 Change slopes of lines

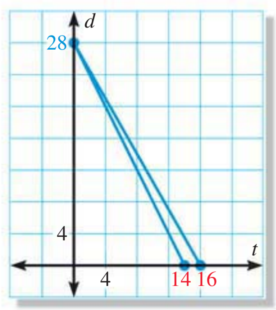
ESCALATORS To get from one floor to another at a library, you can take either the stairs or the escalator. You can climb stairs at a rate of 1.75 feet per second, and the escalator rises at a rate of 2 feet per second. You have to travel a vertical distance of 28 feet. The equations model the vertical distance d (in feet) you have left to travel after t seconds.

Stairs: $d = -1.75t + 28$ **Escalator:** $d = -2t + 28$

a. Graph the equations in the same coordinate plane.

b. How much time do you save by taking the escalator?

Solution



a. Draw the graph of $d = -1.75t + 28$ using the fact that the d-intercept is 28 and the slope is -1.75. Similarly, draw the graph of $d = -2t + 28$. The graphs make sense only in the first quadrant.

b. The equation $d = -1.75t + 28$ has a t-intercept of **16**. The equation $d = -2t + 28$ has a t-intercept of **14**. So, you save $16 - 14 = 2$ seconds by taking the escalator.

✓ GUIDED PRACTICE for Examples 2 and 3

4. Graph the equation $y = -2x + 5$.

5. **WHAT IF?** In Example 3, suppose a person can climb stairs at a rate of 1.4 feet per second. How much time does taking the escalator save?

EXAMPLE 4 Change intercepts of lines

TELEVISION A company produced two 30 second commercials, one for \$300,000 and the second for \$400,000. Each airing of either commercial on a particular station costs \$150,000. The cost C (in thousands of dollars) to produce the first commercial and air it n times is given by $C = 150n + 300$. The cost to produce the second and air it n times is given by $C = 150n + 400$.

a. Graph both equations in the same coordinate plane.

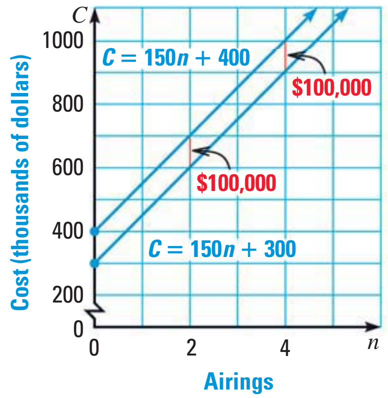
b. Based on the graphs, what is the difference of the costs to produce each commercial and air it 2 times? 4 times? What do you notice about the differences of the costs?

Solution

a. The graphs of the equations are shown.

b. You can see that the vertical distance between the lines is \$100,000 when $n = 2$ and $n = 4$.

The difference of the costs is \$100,000 no matter how many times the commercials are aired.



PARALLEL LINES Two lines in the same plane are **parallel** if they do not intersect. Because slope gives the rate at which a line rises or falls, two nonvertical lines with the same slope are parallel.

EXAMPLE 5 Identify parallel lines

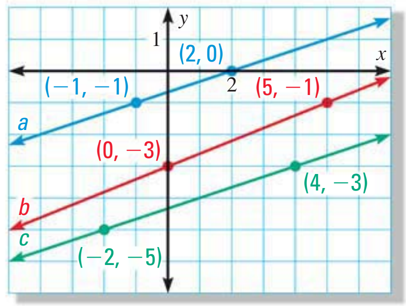
Determine which of the lines are parallel.

Find the slope of each line.

Line *a*: $m = \dfrac{-1 - 0}{-1 - 2} = \dfrac{-1}{-3} = \dfrac{1}{3}$

Line *b*: $m = \dfrac{-3 - (-1)}{0 - 5} = \dfrac{-2}{-5} = \dfrac{2}{5}$

Line *c*: $m = \dfrac{-5 - (-3)}{-2 - 4} = \dfrac{-2}{-6} = \dfrac{1}{3}$



▶ Line a and line c have the same slope, so they are parallel.

✓ GUIDED PRACTICE for Examples 4 and 5

6. **WHAT IF?** In Example 4, suppose that the cost of producing and airing a third commercial is given by $C = 150n + 200$. Graph the equation. Find the difference of the costs of the second commercial and the third.

7. Determine which lines are parallel: line a through $(-1, 2)$ and $(3, 4)$; line b through $(3, 4)$ and $(5, 8)$; line c through $(-9, -2)$ and $(-1, 2)$.

4.5 EXERCISES

HOMEWORK KEY
◯ = **WORKED-OUT SOLUTIONS** on p. WS1 for Exs. 11, 21, and 41
★ = **STANDARDIZED TEST PRACTICE** Exs. 2, 9, 10, 36, 42, and 44

SKILL PRACTICE

1. **VOCABULARY** Copy and complete: Two lines in the same plane are _?_ if they do not intersect.

2. ★ **WRITING** What is the slope-intercept form of a linear equation? *Explain* why this form is called slope-intercept form.

EXAMPLE 1 on p. 244 for Exs. 3–16

SLOPE AND y-INTERCEPT **Identify the slope and y-intercept of the line with the given equation.**

3. $y = 2x + 1$ **4.** $y = -x$ **5.** $y = 6 - 3x$

6. $y = -7 + 5x$ **7.** $y = \frac{2}{3}x - 1$ **8.** $y = -\frac{1}{4}x + 8$

9. ★ **MULTIPLE CHOICE** What is the slope of the line with the equation $y = -18x - 9$?

Ⓐ -18 Ⓑ -9 Ⓒ 9 Ⓓ 18

10. ★ **MULTIPLE CHOICE** What is the y-intercept of the line with the equation $x - 3y = -12$?

Ⓐ -12 Ⓑ -4 Ⓒ 4 Ⓓ 12

REWRITING EQUATIONS **Rewrite the equation in slope-intercept form. Then identify the slope and the y-intercept of the line.**

11. $4x + y = 1$ **12.** $x - y = 6$ **13.** $6x - 3y = -9$

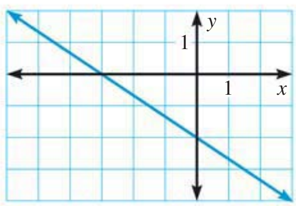
14. $-12x - 4y = 2$ **15.** $2x + 5y = -10$ **16.** $-x - 10y = 20$

EXAMPLE 2 on p. 245 for Exs. 17–29

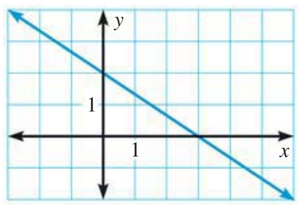
MATCHING EQUATIONS WITH GRAPHS **Match the equation with its graph.**

17. $2x + 3y = 6$ **18.** $2x + 3y = -6$ **19.** $2x - 3y = 6$

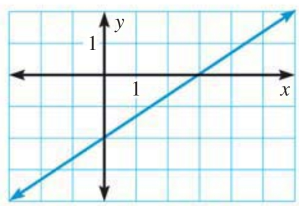
A.



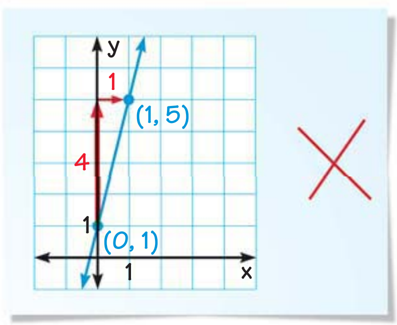
B.



C.



20. **ERROR ANALYSIS** *Describe* and correct the error in graphing the equation $y = 4x - 1$.



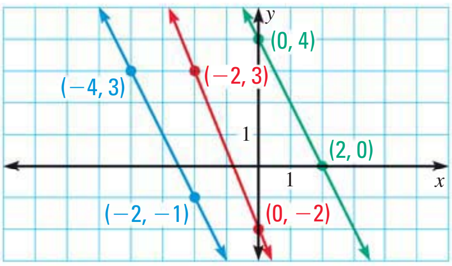
GRAPHING EQUATIONS **Graph the equation.**

21. $y = -6x + 1$
22. $y = 3x + 2$
23. $y = -x + 7$
24. $y = \frac{2}{3}x$
25. $y = \frac{1}{4}x - 5$
26. $y = -\frac{5}{2}x + 2$
27. $7x - 2y = -11$
28. $-8x - 2y = 32$
29. $-x - 0.5y = 2.5$

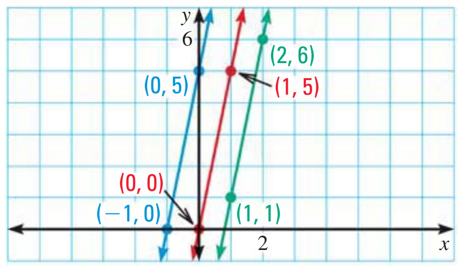
EXAMPLE 5
on p. 246
for Exs. 30–35

PARALLEL LINES **Determine which lines are parallel.**

30.



31.



PARALLEL LINES **Tell whether the graphs of the two equations are parallel lines. *Explain* your reasoning.**

32. $y = 5x - 7$, $5x + y = 7$
33. $y = 3x + 2$, $-7 + 3x = y$
34. $y = -0.5x$, $x + 2y = 18$
35. $4x + y = 3$, $x + 4y = 3$

36. ★ **OPEN-ENDED** Write the equation of a line that is parallel to $6x + y = 24$. *Explain* your reasoning.

REASONING **Find the value of *k* so that the lines through the given points are parallel.**

37. Line 1: $(-4, -2)$ and $(0, 0)$
Line 2: $(2, 7)$ and $(k, 5)$

38. Line 1: $(-1, 9)$ and $(-6, -6)$
Line 2: $(-7, k)$ and $(0, -2)$

39. **CHALLENGE** Find the slope and y-intercept of the graph of the equation $Ax + By = C$ where $B \neq 0$. Use your results to find the slope and y-intercept of the graph of $3x + 2y = 18$.

PROBLEM SOLVING

EXAMPLES 3 and 4
on pp. 245–246
for Exs. 40–44

40. **HOCKEY** Your family spends \$60 on tickets to a hockey game and \$4 per hour for parking. The total cost C (in dollars) is given by $C = 60 + 4t$ where t is the time (in hours) your family's car is parked.

a. Graph the equation.

b. Suppose the parking fee is raised to \$5.50 per hour so that the total cost of tickets and parking for t hours is $C = 60 + 5.5t$. Graph the equation in the same coordinate plane as the equation in part (a).

c. How much more does it cost to go to a game for 4 hours after the parking fee is raised?

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○ = **WORKED-OUT SOLUTIONS** on p. WS1

★ = **STANDARDIZED TEST PRACTICE**

41. **SPEED LIMITS** In 1995 Pennsylvania changed its maximum speed limit on rural interstate highways, as shown below. The diagram also shows the distance d (in miles) a person could travel driving at the maximum speed limit for t hours both before and after 1995.

a. Graph both equations in the same coordinate plane.

b. Use the graphs to find the difference of the distances a person could drive in 3 hours before and after the speed limit was changed.

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42. ★ **SHORT RESPONSE** A service station charges $40 per hour for labor plus the cost of parts to repair a car. Parts can either be ordered from the car dealership for $250 or from a warehouse for $200. The equations below give the total repair cost C (in dollars) for a repair that takes t hours using parts from the dealership or from the warehouse.

Dealership: $C = 40t + 250$ **Warehouse:** $C = 40t + 200$

a. Graph both equations in the same coordinate plane.

b. Use the graphs to find the difference of the costs if the repair takes 3 hours. What if the repair takes 4 hours? What do you notice about the differences of the costs? *Explain*.

43. **FACTORY SHIFTS** Welders at a factory can work one of two shifts. Welders on the first shift earn $12 per hour while workers on the second shift earn $14 per hour. The total amount a (in dollars) a first-shift worker earns is given by $a = 12t$ where t is the time (in hours) worked. The total amount a second-shift worker earns is given by $a = 14t$.

a. Graph both equations in the same coordinate plane. What do the slopes and the a-intercepts of the graphs mean in this situation?

b. How much more money does a welder earn for a 40 hour week if he or she works the second shift rather than the first shift?

44. ★ **EXTENDED RESPONSE** An artist is renting a booth at an art show. A small booth costs $350 to rent. The artist plans to sell framed pictures for $50 each. The profit P (in dollars) the artist makes after selling p pictures is given by $P = 50p - 350$.

a. Graph the equation.

b. If the artist decides to rent a larger booth for $500, the profit is given by $P = 50p - 500$. Graph this equation on the same coordinate plane you used in part (a).

c. The artist can display 80 pictures in the small booth and 120 in the larger booth. If the artist is able to sell all of the pictures, which booth should the artist rent? *Explain*.

45. **CHALLENGE** To use a rock climbing wall at a college, a person who does not attend the college has to pay a \$5 certification fee plus \$3 per visit. The total cost C (in dollars) for a person who does not attend the college is given by $C = 3v + 5$ where v is the number of visits to the rock climbing wall. A student at the college pays only an \$8 certification fee, so the total cost for a student is given by $C = 8$.

a. Graph both equations in the same coordinate plane. At what point do the lines intersect? What does the point of intersection represent?

b. When will a nonstudent pay more than a student? When will a student pay more than a nonstudent? *Explain*.

MIXED REVIEW

PREVIEW
Prepare for Lesson 4.6 in Exs. 52–57.

Simplify the expression. *(p. 96)*

46. $3(x + 24)$ **47.** $5(x - 5)$ **48.** $8(x - 6)$

Solve the equation.

49. $3x + x = 8$ *(p. 141)* **50.** $5(x - 3x) = 15$ *(p. 148)* **51.** $\frac{4}{3}(8x - 3) = 16$ *(p. 148)*

Find the slope of the line that passes through the points. *(p. 235)*

52. (3, 4) and (9, 5) **53.** (4, −4) and (−2, 2) **54.** (−3, −7) and (0, −7)

Solve the proportion. Check your solution. *(p. 168)*

55. $\frac{4}{5} = \frac{x}{50}$ **56.** $\frac{2x}{x+4} = \frac{8}{9}$ **57.** $\frac{7t-2}{8} = \frac{3t-4}{5}$

QUIZ for Lessons 4.4–4.5

Find the slope of the line that passes through the points. *(p. 235)*

1. (3, −11) and (0, 4) **2.** (2, 1) and (8, 4) **3.** (−4, −1) and (−1, −1)

Identify the slope and y-intercept of the line with the given equation. *(p. 244)*

4. $y = -x + 9$ **5.** $2x + 9y = -18$ **6.** $-x + 6y = 21$

Graph the equation. *(p. 244)*

7. $y = -2x + 11$ **8.** $y = \frac{5}{3}x - 8$ **9.** $-3x - 4y = -12$

10. **RED OAKS** Red oak trees grow at a rate of about 2 feet per year. You buy and plant two red oak trees, one that is 6 feet tall and one that is 8 feet tall. The height h (in feet) of the shorter tree can be modeled by $h = 2t + 6$ where t is the time (in years) since you planted the tree. The height of the taller tree can be modeled by $h = 2t + 8$. *(p. 244)*

a. Graph both equations in the same coordinate plane.

b. Use the graphs to find the difference of the heights of the trees 5 years after you plant them. What is the difference after 10 years? What do you notice about the difference of the heights of the two trees?

Extension
Use after Lesson 4.5

Solve Linear Equations by Graphing

GOAL Use graphs to solve linear equations.

In Chapter 3, you learned how to solve linear equations in one variable algebraically. You can also solve linear equations graphically.

KEY CONCEPT *For Your Notebook*

Steps for Solving Linear Equations Graphically

Use the following steps to solve a linear equation in one variable graphically.

STEP 1 **Write** the equation in the form $ax + b = 0$.

STEP 2 **Write** the related function $y = ax + b$.

STEP 3 **Graph** the equation $y = ax + b$.

The solution of $ax + b = 0$ is the x-intercept of the graph of $y = ax + b$.

EXAMPLE 1 Solve an equation graphically

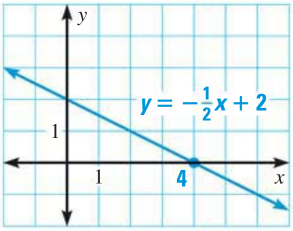
Solve $\frac{5}{2}x + 2 = 3x$ graphically. Check your solution algebraically.

Solution

STEP 1 **Write** the equation in the form $ax + b = 0$.

$\frac{5}{2}x + 2 = 3x$ **Write original equation.**

$-\frac{1}{2}x + 2 = 0$ **Subtract $3x$ from each side.**



STEP 2 **Write** the related function $y = -\frac{1}{2}x + 2$.

STEP 3 **Graph** the equation $y = -\frac{1}{2}x + 2$. The x-intercept is 4.

▶ The solution of $\frac{5}{2}x + 2 = 3x$ is 4.

CHECK Use substitution.

$\frac{5}{2}x + 2 = 3x$ **Write original equation.**

$\frac{5}{2}(4) + 2 \stackrel{?}{=} 3(4)$ **Substitute 4 for x.**

$10 + 2 = 12$ **Simplify.**

$12 = 12$ ✓ **Solution checks.**

EXAMPLE 2 Approximate a real-world solution

POPULATION The United States population P (in millions) can be modeled by the function $P = 2.683t + 213.1$ where t is the number of years since 1975. In approximately what year will the population be 350 million?

Solution

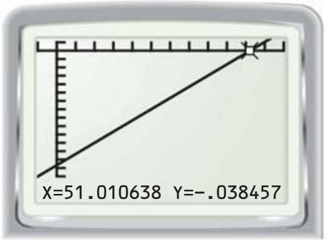
Substitute 350 for P in the linear model. You can answer the question by solving the resulting linear equation $350 = 2.683t + 213.1$.

STEP 1 **Write** the equation in the form $ax + b = 0$.

$350 = 2.683t + 213.1$	**Write equation.**
$0 = 2.683t - 136.9$	**Subtract 350 from each side.**
$0 = 2.683x - 136.9$	**Substitute *x* for *t*.**

STEP 2 **Write** the related function: $y = 2.683x - 136.9$.

STEP 3 **Graph** the related function on a graphing calculator. Use the *trace* feature to approximate the x-intercept. You will know that you've crossed the x-axis when the y-values change from negative to positive. The x-intercept is about 51.



SET THE WINDOW
Use the following viewing window for Example 2.
Xmin=−5
Xmax=60
Xscl=5
Ymin=−150
Ymax=10
Yscl=10

▶ Because x is the number of years since 1975, you can estimate that the population will be 350 million about 51 years after 1975, or in 2026.

PRACTICE

EXAMPLE 1
on p. 251
for Exs. 1–6

Solve the equation graphically. Then check your solution algebraically.

1. $6x + 5 = -7$
2. $-7x + 18 = -3$
3. $2x - 4 = 3x$
4. $\frac{1}{2}x - 3 = 2x$
5. $-4 + 9x = -3x + 2$
6. $10x - 18x = 4x - 6$

EXAMPLE 2
on p. 252
for Exs. 7–9

7. **CABLE TELEVISION** The number s (in millions) of cable television subscribers can be modeled by the function $s = 1.79t + 51.1$ where t is the number of years since 1990. Use a graphing calculator to approximate the year when the number of subscribers was 70 million.

8. **EDUCATION** The number b (in thousands) of bachelor's degrees in Spanish earned in the U.S. can be modeled by the function $b = 0.281t + 4.26$ where t is the number of years since 1990. Use a graphing calculator to approximate the year when the number of degrees will be 9000.

9. **TRAVEL** The number of miles m (in billions) traveled by vehicles in New York can be modeled by $m = 2.56t + 113$ where t is the number of years since 1994. Use a graphing calculator to approximate the year in which the number of vehicle miles of travel in New York was 130 billion.

4.6 Model Direct Variation

Before	You wrote and graphed linear equations.
Now	You will write and graph direct variation equations.
Why?	So you can model distance traveled, as in Ex. 40.

Key Vocabulary
- **direct variation**
- **constant of variation**

Two variables x and y show **direct variation** provided $y = ax$ and $a \neq 0$. The nonzero number a is called the **constant of variation**, and y is said to *vary directly* with x.

The equation $y = 5x$ is an example of direct variation, and the constant of variation is 5. The equation $y = x + 5$ is *not* an example of direct variation.

EXAMPLE 1 Identify direct variation equations

Tell whether the equation represents direct variation. If so, identify the constant of variation.

a. $2x - 3y = 0$ **b.** $-x + y = 4$

Solution

To tell whether an equation represents direct variation, try to rewrite the equation in the form $y = ax$.

a. $2x - 3y = 0$ Write original equation.

$-3y = -2x$ Subtract $2x$ from each side.

$y = \frac{2}{3}x$ Simplify.

▶ Because the equation $2x - 3y = 0$ can be rewritten in the form $y = ax$, it represents direct variation. The constant of variation is $\frac{2}{3}$.

b. $-x + y = 4$ Write original equation.

$y = x + 4$ Add x to each side.

▶ Because the equation $-x + y = 4$ cannot be rewritten in the form $y = ax$, it does not represent direct variation.

✓ GUIDED PRACTICE for Example 1

Tell whether the equation represents direct variation. If so, identify the constant of variation.

1. $-x + y = 1$ **2.** $2x + y = 0$ **3.** $4x - 5y = 0$

DIRECT VARIATION GRAPHS Notice that a direct variation equation, $y = ax$, is a linear equation in slope-intercept form, $y = mx + b$, with $m = a$ and $b = 0$. The graph of a direct variation equation is a line with a slope of a and a y-intercept of 0. So, the line passes through the origin.

EXAMPLE 2 Graph direct variation equations

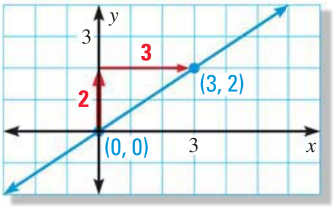
Graph the direct variation equation.

a. $y = \frac{2}{3}x$

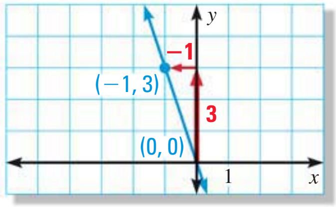
b. $y = -3x$

Solution

a. Plot a point at the origin. The slope is equal to the constant of variation, or $\frac{2}{3}$. Find and plot a second point, then draw a line through the points.



b. Plot a point at the origin. The slope is equal to the constant of variation, or -3. Find and plot a second point, then draw a line through the points.



DRAW A GRAPH

If the constant of variation is positive, the graph of $y = ax$ passes through Quadrants I and III. If the constant of variation is negative, the graph of $y = ax$ passes through Quadrants II and IV.

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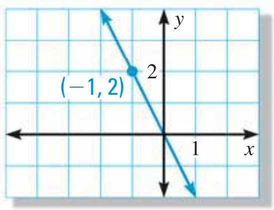
EXAMPLE 3 Write and use a direct variation equation

The graph of a direct variation equation is shown.

a. Write the direct variation equation.

b. Find the value of y when $x = 30$.



Solution

a. Because y varies directly with x, the equation has the form $y = ax$. Use the fact that $y = 2$ when $x = -1$ to find a.

$y = ax$	Write direct variation equation.
$2 = a(-1)$	Substitute.
$-2 = a$	Solve for a.

▶ A direct variation equation that relates x and y is $y = -2x$.

b. When $x = 30$, $y = -2(30) = -60$.

✓ GUIDED PRACTICE for Examples 2 and 3

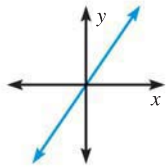
4. Graph the direct variation equation $y = 2x$.

5. The graph of a direct variation equation passes through the point $(4, 6)$. Write the direct variation equation and find the value of y when $x = 24$.

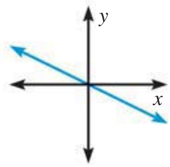
KEY CONCEPT — *For Your Notebook*

Properties of Graphs of Direct Variation Equations

- The graph of a direct variation equation is a line through the origin.
- The slope of the graph of $y = ax$ is a.



$a > 0$



$a < 0$

EXAMPLE 4 Solve a multi-step problem

ANOTHER WAY
For alternative methods for solving Example 4, turn to page 260 for the **Problem Solving Workshop**.

SALTWATER AQUARIUM The number s of tablespoons of sea salt needed in a saltwater fish tank varies directly with the number w of gallons of water in the tank. A pet shop owner recommends adding 100 tablespoons of sea salt to a 20 gallon tank.

- Write a direct variation equation that relates w and s.
- How many tablespoons of salt should be added to a 30 gallon saltwater fish tank?

Solution

STEP 1 **Write** a direct variation equation. Because s varies directly with w, you can use the equation $s = aw$. Also use the fact that $s = 100$ when $w = 20$.

$s = aw$ **Write direct variation equation.**

$100 = a(20)$ **Substitute.**

$5 = a$ **Solve for *a*.**

RECOGNIZE RATE OF CHANGE
The value of a in Example 4 is a rate of change: 5 tablespoons of sea salt per gallon of water.

▶ A direct variation equation that relates w and s is $s = 5w$.

STEP 2 **Find** the number of tablespoons of salt that should be added to a 30 gallon saltwater fish tank. Use your direct variation equation from Step 1.

$s = 5w$ **Write direct variation equation.**

$s = 5(30)$ **Substitute 30 for *w*.**

$s = 150$ **Simplify.**

▶ You should add 150 tablespoons of salt to a 30 gallon fish tank.

✓ GUIDED PRACTICE for Example 4

6. WHAT IF? In Example 4, suppose the fish tank is a 25 gallon tank. How many tablespoons of salt should be added to the tank?

RATIOS The direct variation equation $y = ax$ can be rewritten as $\frac{y}{x} = a$ for $x \neq 0$. So, in a direct variation, the ratio of y to x is constant for all nonzero data pairs (x, y).

EXAMPLE 5 Use a direct variation model

ONLINE MUSIC The table shows the cost C of downloading s songs at an Internet music site.

a. Explain why C varies directly with s.

b. Write a direct variation equation that relates s and C.

Number of songs, s	Cost, C (dollars)
3	2.97
5	4.95
7	6.93

CHECK RATIOS
For real-world data, the ratios may not be exactly equal. You may still be able to use a direct variation model when the ratios are approximately equal.

Solution

a. To explain why C varies directly with s, compare the ratios $\frac{C}{s}$ for all data pairs (s, C): $\frac{2.97}{3} = \frac{4.95}{5} = \frac{6.93}{7} = 0.99$.

Because the ratios all equal 0.99, C varies directly with s.

b. A direct variation equation is $C = 0.99s$.

✓ GUIDED PRACTICE for Example 5

7. **WHAT IF?** In Example 5, suppose the website charges a total of \$1.99 for the first 5 songs you download and \$.99 for each song after the first 5. Is it reasonable to use a direct variation model for this situation? *Explain.*

4.6 EXERCISES

HOMEWORK KEY

○ = **WORKED-OUT SOLUTIONS** on p. WS1 for Exs. 7, 21, and 43

★ = **STANDARDIZED TEST PRACTICE** Exs. 2, 9, 28, 38, 43, 44, and 46

◆ = **MULTIPLE REPRESENTATIONS** Ex. 45

SKILL PRACTICE

1. **VOCABULARY** Copy and complete: Two variables x and y show _?_ provided $y = ax$ and $a \neq 0$.

2. ★ **WRITING** A line has a slope of -3 and a y-intercept of 4. Is the equation of the line a direct variation equation? *Explain.*

EXAMPLE 1
on p. 253
for Exs. 3–10

IDENTIFYING DIRECT VARIATION EQUATIONS **Tell whether the equation represents direct variation. If so, identify the constant of variation.**

3. $y = x$ | **4.** $y = 5x - 1$ | **5.** $2x + y = 3$

6. $x - 3y = 0$ | **7.** $8x + 2y = 0$ | **8.** $2.4x + 6 = 1.2y$

9. ★ **MULTIPLE CHOICE** Which equation is a direct variation equation?

Ⓐ $y = 7 - 3x$ Ⓑ $3x - 7y = 1$ Ⓒ $3x - 7y = 0$ Ⓓ $3y = 7x - 1$

10. **ERROR ANALYSIS** *Describe* and correct the error in identifying the constant of variation for the direct variation equation $-5x + 3y = 0$.

$$-5x + 3y = 0$$
$$3y = 5x$$
The constant of variation is 5.

EXAMPLE 2
on p. 254
for Exs. 11–22

GRAPHING EQUATIONS **Graph the direct variation equation.**

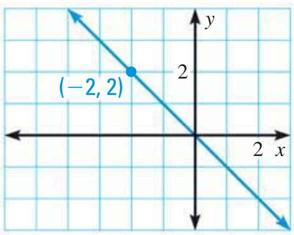
11. $y = x$ **12.** $y = 3x$ **13.** $y = -4x$ **14.** $y = 5x$

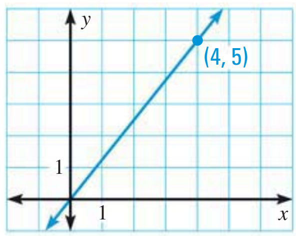
15. $y = \frac{4}{3}x$ **16.** $y = \frac{1}{2}x$ **17.** $y = -\frac{1}{3}x$ **18.** $y = -\frac{3}{2}x$

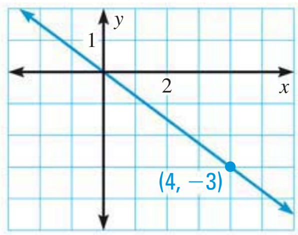
19. $12y = -24x$ **20.** $10y = 25x$ **21.** $4x + y = 0$ **22.** $y - 1.25x = 0$

EXAMPLE 3
on p. 254
for Exs. 23–25

WRITING EQUATIONS **The graph of a direct variation equation is shown. Write the direct variation equation. Then find the value of *y* when $x = 8$.**

23.


24.


25.


IDENTIFYING DIRECT VARIATION EQUATIONS **Tell whether the table represents direct variation. If so, write the direct variation equation.**

26.

x	1	2	3	4	6
y	5	10	15	20	30

27.

x	−3	−1	1	3	5
y	−2	0	2	4	6

28. ★ **WRITING** A student says that a direct variation equation can be used to model the data in the table. *Explain* why the student is mistaken.

x	2	4	8	16
y	1	2	4	6

WRITING EQUATIONS **Given that *y* varies directly with *x*, use the specified values to write a direct variation equation that relates *x* and *y*.**

29. $x = 3, y = 9$ **30.** $x = 2, y = 26$ **31.** $x = 14, y = 7$

32. $x = 15, y = -5$ **33.** $x = -2, y = -2$ **34.** $x = -18, y = -4$

35. $x = \frac{1}{4}, y = 1$ **36.** $x = -6, y = 15$ **37.** $x = -5.2, y = 1.4$

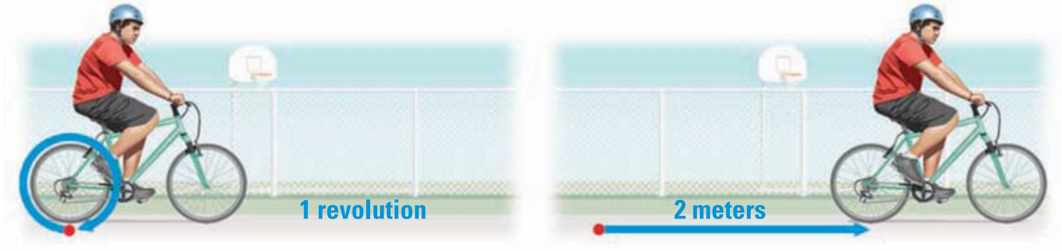
38. ★ **WRITING** If *y* varies directly with *x*, does *x* vary directly with *y*? If so, what is the relationship between the constants of variation? *Explain*.

39. **CHALLENGE** The slope of a line is $-\frac{1}{3}$, and the point $(-6, 2)$ lies on the line. Use the formula for the slope of a line to determine if the equation of the line is a direct variation equation.

PROBLEM SOLVING

EXAMPLE 4
on p. 255
for Exs. 40–42

40. BICYCLES The distance d (in meters) you travel on a bicycle varies directly with the number r of revolutions that the rear tire completes. You travel about 2 meters on a mountain bike for every revolution of the tire.



a. Write a direct variation equation that relates r and d.

b. How many meters do you travel in 1500 tire revolutions?

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41. VACATION TIME At one company, the amount of vacation v (in hours) an employee earns varies directly with the amount of time t (in weeks) he or she works. An employee who works 2 weeks earns 3 hours of vacation.

a. Write a direct variation equation that relates t and v.

b. How many hours of vacation time does an employee earn in 8 weeks?

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42. LANDSCAPING Landscapers plan to spread a layer of stone on a path. The number s of bags of stone needed depends on the depth d (in inches) of the layer. They need 10 bags to spread a layer of stone that is 2 inches deep. Write a direct variation equation that relates d and s. Then find the number of bags needed to spread a layer that is 3 inches deep.

EXAMPLE 5
on p. 256
for Exs. 43–44

43. ★ **SHORT RESPONSE** At a recycling center, computers and computer accessories can be recycled for a fee f based on weight w, as shown in the table.

Weight, w (pounds)	Fee, f (dollars)
10	2.50
15	3.75
30	7.50

a. *Explain* why f varies directly with w.

b. Write a direct variation equation that relates w and f. Find the total recycling fee for a computer that weighs 18 pounds and a printer that weighs 10 pounds.

44. ★ **SHORT RESPONSE** You can buy gold chain by the inch. The table shows the price of gold chain for various lengths.

Length, ℓ (inches)	7	9	16	18
Price, p (dollars)	8.75	11.25	20.00	22.50

a. *Explain* why p varies directly with ℓ.

b. Write a direct variation equation that relates ℓ and p. If you have \$30, what is the longest chain that you can buy?

45. **MULTIPLE REPRESENTATIONS** The total cost of riding the subway to and from school every day is \$1.50.

a. **Making a Table** Make a table that shows the number d of school days and the total cost C (in dollars) for trips to and from school for some values of d. Assume you travel to school once each school day and home from school once each school day.

b. **Drawing a Graph** Graph the ordered pairs from the table and draw a ray through them.

c. **Writing an Equation** Write an equation of the graph from part (b). Is it a direct variation equation? *Explain.* If there are 22 school days in one month, what will it cost to ride the subway to and from school for that month?

46. ★ **EXTENDED RESPONSE** The table shows the average number of field goals attempted t and the average number of field goals made m per game for all NCAA Division I women's basketball teams for 9 consecutive seasons.

Attempted field goals, t	61.8	61.9	61.8	60.8	59.5	59.0	58.9	59.2	58.4
Field goals made, m	25.7	25.6	25.6	25.2	24.5	24.6	24.5	24.3	24.0

a. **Write** Why is it reasonable to use a direct variation model for this situation? Write a direct variation equation that relates t and m. Find the constant of variation to the nearest tenth.

b. **Estimate** The highest average number of attempted field goals in one season was 66.2. Estimate the number of field goals made that season.

c. **Explain** If the average number of field goals made was increasing rather than decreasing and the number of attempted field goals continued to decrease, would the data show direct variation? *Explain.*

47. **CHALLENGE** In Exercise 40, you found an equation showing that the distance traveled on a bike varies directly with the number of revolutions that the rear tire completes. The number r of tire revolutions varies directly with the number p of pedal revolutions. In a particular gear, you travel about 1.3 meters for every 5 revolutions of the pedals. Show that distance traveled varies directly with pedal revolutions.

MIXED REVIEW

Graph the equation.

48. $y = -8$ (p. 215)
49. $x = 6$ (p. 215)
50. $2x + y = 4$ (p. 225)
51. $-2x + 5y = -30$ (p. 225)
52. $0.4x + 2y = 6$ (p. 225)
53. $y = 2x - 5$ (p. 244)
54. $y = \frac{1}{3}x$ (p. 244)
55. $y = -x + 3$ (p. 244)
56. $y = -\frac{3}{2}x + 2$ (p. 244)

PREVIEW
Prepare for Lesson 4.7 in Exs. 57–62.

Identify the slope and y-intercept of the line with the given equation. (p. 244)

57. $y = 3x + 5$
58. $y = -3x$
59. $y = 2x - 5$
60. $y = 4x - 11$
61. $y = \frac{4}{5}x - 3$
62. $y = \frac{5}{4}x + 3.1$

PROBLEM SOLVING WORKSHOP
LESSON 4.6

Using ALTERNATIVE METHODS

Another Way to Solve Example 4, page 255

MULTIPLE REPRESENTATIONS In Example 4 on page 255, you saw how to solve the problem about how much salt to add to a saltwater fish tank by writing and using a direct variation equation. You can also solve the problem using a graph or a proportion.

PROBLEM

SALTWATER AQUARIUM The number s of tablespoons of sea salt needed in a saltwater fish tank varies directly with the number w of gallons of water in the tank. A pet shop owner recommends adding 100 tablespoons of sea salt to a 20 gallon tank. How many tablespoons of salt should be added to a 30 gallon saltwater fish tank?

METHOD 1

Using a Graph An alternative approach is to use a graph.

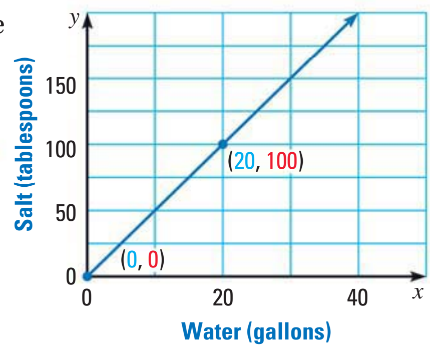
STEP 1 **Read** the problem. It tells you an amount of salt for a certain size fish tank. You can also assume that if a fishtank has no water, then no salt needs to be added. Write ordered pairs for this information.

Number of gallons → (20, 100) ← Tablespoons of salt

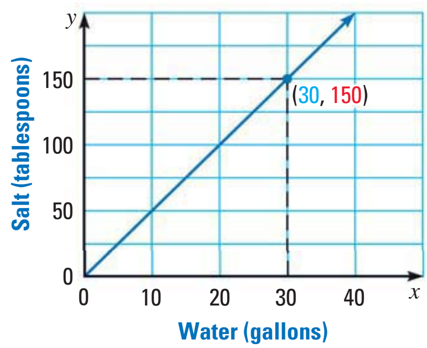
(0, 0)

STEP 2 **Graph** the ordered pairs. Draw a line through the points.

The coordinates of points on the line give the amounts of salt that should be added to fish tanks of various sizes.



STEP 3 **Find** the point on the graph that has an x-coordinate of 30. The y-coordinate of this point is 150, so 150 tablespoons of salt should be added to a 30 gallon tank.



METHOD 2

Writing a Proportion Another alternative approach is to write and solve a proportion.

STEP 1 **Write** a proportion involving two ratios that each compare the amount of water (in gallons) to the amount of salt (in tablespoons).

$$\frac{20}{100} = \frac{30}{s} \begin{array}{l} \longleftarrow \text{amount of water (gallons)} \\ \longleftarrow \text{amount of salt (tablespoons)} \end{array}$$

STEP 2 **Solve** the proportion.

$\frac{20}{100} = \frac{30}{s}$ **Write proportion.**

$20s = 100 \cdot 30$ **Cross products property**

$20s = 3000$ **Simplify.**

$s = 150$ **Divide each side by 20.**

▸ You should add 150 tablespoons of salt to a 30 gallon tank.

CHECK Check your answer by writing each ratio in simplest form.

$$\frac{20}{100} = \frac{1}{5} \text{ and } \frac{30}{150} = \frac{1}{5}$$

Because each ratio simplifies to $\frac{1}{5}$, the answer is correct.

PRACTICE

1. **WHAT IF?** Suppose the fish tank in the problem above is a 22 gallon tank. How many tablespoons of salt should be added to the tank? *Describe* which method you used to solve this problem.

2. **ADVERTISING** A local newspaper charges by the word for printing classified ads. A 14 word ad costs $5.88. How much would a 21 word ad cost? Solve this problem using two different methods.

3. **REASONING** In Exercise 2, how can you quickly determine the cost of a 7 word ad? *Explain* how you could use the cost of a 7 word ad to solve the problem.

4. **NUTRITION** A company sells fruit smoothies in two sizes of bottles: 6 fluid ounces and 10 fluid ounces. You know that a 6 ounce bottle contains 96 milligrams of sodium. How many milligrams of sodium does a 10 ounce bottle contain?

5. **ERROR ANALYSIS** A student solved the problem in Exercise 4 as shown. *Describe* and correct the error made.

Let x = the number of milligrams of sodium in a 10 ounce bottle.

$$\frac{6}{x} = \frac{10}{96}$$

$$576 = 10x$$

$$57.6 = x$$

6. **SLEEPING** You find an online calculator that calculates the number of calories you burn while sleeping. The results for various sleeping times are shown. About how many more calories would you burn by sleeping for 9.5 hours than for 8 hours? Choose any method for solving the problem.

Hours of sleep	6.5	7	8.5	9
Calories burned	390	420	510	540

4.7 Graph Linear Functions

Before You graphed linear equations and functions.

Now You will use function notation.

Why? So you can model an animal population, as in Example 3.

Key Vocabulary
- function notation
- family of functions
- parent linear function

You have seen linear functions written in the form $y = mx + b$. By naming a function f, you can write it using **function notation**.

$$f(x) = mx + b \qquad \text{Function notation}$$

The symbol $f(x)$ is another name for y and is read as "the value of f at x," or simply as "f of x." It does *not* means f times x. You can use letters other than f, such as g or h, to name functions.

EXAMPLE 1 Standardized Test Practice

What is the value of the function $f(x) = 3x - 15$ when $x = -3$?

Ⓐ -24 Ⓑ -6 Ⓒ -2 Ⓓ 8

Solution

$f(x) = 3x - 15$ Write original function.

$f(-3) = 3(-3) - 15$ Substitute -3 for x.

$= -24$ Simplify.

▶ The correct answer is A. Ⓐ Ⓑ Ⓒ Ⓓ

GUIDED PRACTICE for Example 1

1. Evaluate the function $h(x) = -7x$ when $x = 7$.

EXAMPLE 2 Find an x-value

For the function $f(x) = 2x - 10$, find the value of x so that $f(x) = 6$.

$f(x) = 2x - 10$ Write original function.

$6 = 2x - 10$ Substitute 6 for $f(x)$.

$8 = x$ Solve for x.

▶ When $x = 8$, $f(x) = 6$.

DOMAIN AND RANGE The domain of a function consists of the values of x for which the function is defined. The range consists of the values of $f(x)$ where x is in the domain of f. The graph of a function f is the set of all points $(x, f(x))$.

EXAMPLE 3 Graph a function

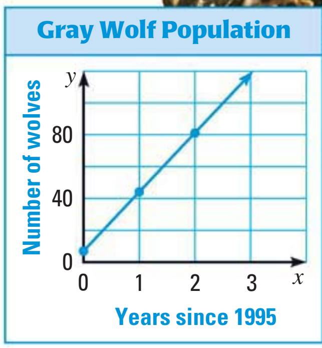
INTERPRET MODELS
The rate of change in the wolf population actually varied over time. The model simplifies the situation by assuming a steady rate of change.

GRAY WOLF The gray wolf population in central Idaho was monitored over several years for a project aimed at boosting the number of wolves. The number of wolves can be modeled by the function $f(x) = 37x + 7$ where x is the number of years since 1995. Graph the function and identify its domain and range.

Solution

To graph the function, make a table.

x	$f(x)$
0	$37(0) + 7 = 7$
1	$37(1) + 7 = 44$
2	$37(2) + 7 = 81$



The domain of the function is $x \geq 0$. From the graph or table, you can see that the range of the function is $f(x) \geq 7$.

✓ GUIDED PRACTICE for Examples 2 and 3

2. **WOLF POPULATION** Use the model from Example 3 to find the value of x so that $f(x) = 155$. *Explain* what the solution means in this situation.

FAMILIES OF FUNCTIONS A **family of functions** is a group of functions with similar characteristics. For example, functions that have the form $f(x) = mx + b$ constitute the family of *linear* functions.

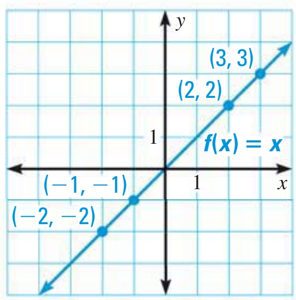
KEY CONCEPT *For Your Notebook*

Parent Function for Linear Functions

The most basic linear function in the family of all linear functions, called the **parent linear function**, is:

$$f(x) = x$$

The graph of the parent linear function is shown.



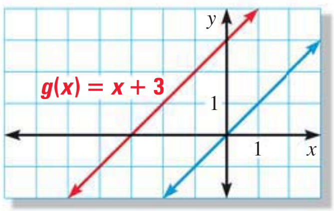
EXAMPLE 4 Compare graphs with the graph $f(x) = x$

Graph the function. Compare the graph with the graph of $f(x) = x$.

a. $g(x) = x + 3$ **b.** $h(x) = 2x$

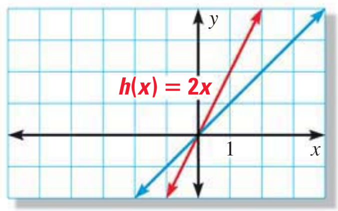
Solution

a.



Because the graphs of g and f have the same slope, $m = 1$, the lines are parallel. Also, the y-intercept of the graph of g is 3 more than the y-intercept of the graph of f.

b.



Because the slope of the graph of h is greater than the slope of the graph of f, the graph of h rises faster from left to right. The y-intercept for both graphs is 0, so both lines pass through the origin.

✓ GUIDED PRACTICE for Example 4

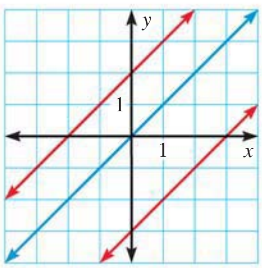
3. Graph $h(x) = -3x$. Compare the graph with the graph of $f(x) = x$.

CONCEPT SUMMARY *For Your Notebook*

Comparing Graphs of Linear Functions with the Graph of $f(x) = x$

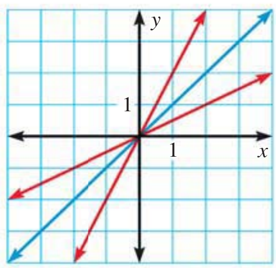
Changing m or b in the general linear function $g(x) = mx + b$ creates families of linear functions whose graphs are related to the graph of $f(x) = x$.

$g(x) = x + b$



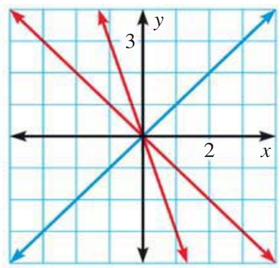
- The graphs have the same slope, but different y-intercepts.
- Graphs of this family are vertical translations of the graph of $f(x) = x$.

$g(x) = mx$ where $m > 0$



- The graphs have different (positive) slopes, but the same y-intercept.
- Graphs of this family are vertical stretches or shrinks of the graph of $f(x) = x$.

$g(x) = mx$ where $m < 0$



- The graphs have different (negative) slopes, but the same y-intercept.
- Graphs of this family are vertical stretches or shrinks with reflections in the x-axis of the graph of $f(x) = x$.

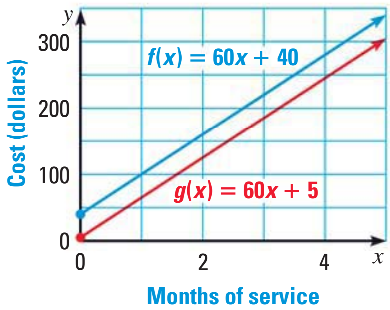
EXAMPLE 5 Graph real-world functions

CABLE A cable company charges new customers \$40 for installation and \$60 per month for its service. The cost to the customer is given by the function $f(x) = 60x + 40$ where x is the number of months of service. To attract new customers, the cable company reduces the installation fee to \$5. A function for the cost with the reduced installation fee is $g(x) = 60x + 5$. Graph both functions. How is the graph of g related to the graph of f?

Solution

REVIEW TRANSFORMATIONS
For help with transformations, see pp. 922–923.

The graphs of both functions are shown. Both functions have a slope of 60, so they are parallel. The y-intercept of the graph of g is 35 less than the graph of f. So, the graph of g is a vertical translation of the graph of f.



✓ GUIDED PRACTICE for Example 5

4. **WHAT IF?** In Example 5, suppose the monthly fee is \$70 so that the cost to the customer is given by $h(x) = 70x + 40$. Graph f and h in the same coordinate plane. How is the graph of h related to the graph of f?

4.7 EXERCISES

HOMEWORK KEY
○ = **WORKED-OUT SOLUTIONS** on p. WS1 for Exs. 3, 17, and 39
★ = **STANDARDIZED TEST PRACTICE** Exs. 2, 13, 22, 35, 36, 44, and 45

SKILL PRACTICE

1. **VOCABULARY** When you write the function $y = 3x + 12$ as $f(x) = 3x + 12$, you are using _?_.

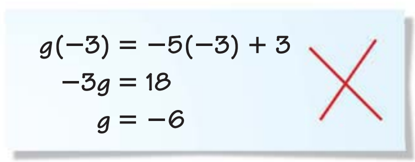
2. ★ **WRITING** Would the functions $f(x) = -9x + 12$, $g(x) = -9x - 2$, and $h(x) = -9x$ be considered a family of functions? *Explain.*

EXAMPLE 1
on p. 262 for Exs. 3–13

EVALUATING FUNCTIONS Evaluate the function when $x = -2$, 0, and 3.

3. $f(x) = 12x + 1$
4. $g(x) = -3x + 5$
5. $p(x) = -8x - 2$
6. $h(x) = 2.25x$
7. $m(x) = -6.5x$
8. $f(x) = -0.75x - 1$
9. $s(x) = \frac{2}{5}x + 3$
10. $d(x) = -\frac{3}{2}x + 5$
11. $h(x) = \frac{3}{4}x - 6$

12. **ERROR ANALYSIS** *Describe* and correct the error in evaluating the function $g(x) = -5x + 3$ when $x = -3$.



13. ★ **MULTIPLE CHOICE** Given $f(x) = -6.8x + 5$, what is the value of $f(-2)$?

Ⓐ -18.6 Ⓑ -8.6 Ⓒ 8.6 Ⓓ 18.6

EXAMPLE 2
on p. 262
for Exs. 14–22

FINDING X-VALUES **Find the value of x so that the function has the given value.**

14. $f(x) = 6x + 9; 3$
15. $g(x) = -x + 5; 2$
16. $h(x) = -7x + 12; -9$
17. $j(x) = 4x + 11; -13$
18. $m(x) = 9x - 5; -2$
19. $n(x) = -2x - 21; -6$
20. $p(x) = -12x - 36; -3$
21. $q(x) = 8x - 32; -4$

22. ★ **MULTIPLE CHOICE** What value of x makes $f(x) = 5$ if $f(x) = -2x + 25$?

Ⓐ -15 Ⓑ -10 Ⓒ 10 Ⓓ 15

EXAMPLE 4
on p. 264
for Exs. 23–34

TRANSFORMATIONS OF LINEAR FUNCTIONS **Graph the function. Compare the graph with the graph of $f(x) = x$.**

23. $g(x) = x + 5$
24. $h(x) = 6 + x$
25. $q(x) = x - 1$
26. $m(x) = x - 6$
27. $d(x) = x + 7$
28. $t(x) = x - 3$
29. $r(x) = 4x$
30. $w(x) = 5x$
31. $h(x) = -3x$
32. $k(x) = -6x$
33. $g(x) = \frac{1}{3}x$
34. $m(x) = -\frac{7}{2}x$

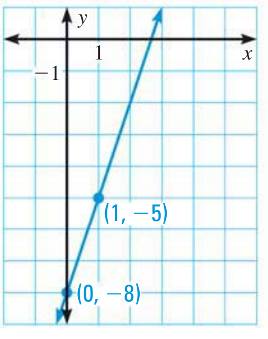
35. ★ **MULTIPLE CHOICE** The graph of which function is shown?

Ⓐ $f(x) = 3x + 8$

Ⓑ $f(x) = 3x - 8$

Ⓒ $f(x) = 8x + 3$

Ⓓ $f(x) = 8x - 3$



36. ★ **OPEN-ENDED** In this exercise you will compare the graphs of linear functions when their slopes and y-intercepts are changed.

a. Choose a linear function of the form $f(x) = mx + b$ where $m \neq 0$. Then graph the function.

b. Using the same m and b values as in part (a), graph the function $g(x) = 2mx + b$. How are the slope and y-intercept of the graph of g related to the slope and y-intercept of the graph of f?

c. Using the same m and b values as in part (a), graph the function $h(x) = mx + (b - 3)$. How are the slope and y-intercept of the graph of h related to the slope and y-intercept of the graph of f?

37. **REASONING** How is the graph of $g(x) = 1$ related to the graph of $h(x) = -1$?

38. **CHALLENGE** Suppose that $f(x) = 4x + 7$ and $g(x) = 2x$. What is a rule for $g(f(x))$? What is a rule for $f(g(x))$?

○ = **WORKED-OUT SOLUTIONS** on p. WS1

★ = **STANDARDIZED TEST PRACTICE**

PROBLEM SOLVING

EXAMPLE 3 on p. 263 for Exs. 39–41

39. MOVIE TICKETS The average price of a movie ticket in the United States from 1980 to 2000 can be modeled by the function $f(x) = 0.10x + 2.75$ where x is the number of years since 1980.

a. Graph the function and identify its domain and range.

b. Find the value of x so that $f(x) = 4.55$. *Explain* what the solution means in this situation.

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40. DVD PLAYERS The number (in thousands) of DVD players sold in the United States from 1998 to 2003 can be modeled by $f(x) = 4250x + 330$ where x is the number of years since 1998.

a. Graph the function and identify its domain and range.

b. Find the value of x so that $f(x) = 13{,}080$. *Explain* what the solution means in this situation.

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41. IN-LINE SKATING An in-line skater's average speed is 10 miles per hour. The distance traveled after skating for x hours is given by the function $d(x) = 10x$. Graph the function and identify its domain and range. How long did it take the skater to travel 15 miles? *Explain*.

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EXAMPLE 5 on p. 265 for Exs. 42–43

42. HOME SECURITY A home security company charges new customers $155 for the installation of security equipment and a monthly fee of $40. To attract more customers, the company reduces its installation fee to $75. The functions below give the total cost for x months of service:

Regular fee: $f(x) = 40x + 155$ **Reduced fee:** $g(x) = 40x + 75$

Graph both functions. How is the graph of g related to the graph of f?

43. THEATERS A ticket for a play at a theater costs $16. The revenue (in dollars) generated from the sale of x tickets is given by $s(x) = 16x$. The theater managers raise the cost of tickets to $20. The revenue generated from the sale of x tickets at that price is given by $r(x) = 20x$. Graph both functions. How is the graph of r related to the graph of s?

44. ★ EXTENDED RESPONSE The cost of supplies, such as mustard and napkins, a pretzel vendor needs for one day is $75. Each pretzel costs the vendor $.50 to make. The total daily cost to the vendor is given by $C(x) = 0.5x + 75$ where x is the number of pretzels the vendor makes.

a. Graph Graph the cost function.

b. Graph The vendor sells each pretzel for $3. The revenue is given by $R(x) = 3x$ where x is the number of pretzels sold. Graph the function.

c. Explain The vendor's profit is the difference of the revenue and the cost. *Explain* how you could use the graphs to find the vendor's profit for any given number of pretzels made and sold.

45. ★ **EXTENDED RESPONSE** The number of hours of daylight in Austin, Texas, during the month of March can be modeled by the function $\ell(x) = 0.03x + 11.5$ where x is the day of the month.

a. Graph Graph the function and identify its domain and range.

b. Graph The number of hours of darkness can be modeled by the function $d(x) = 24 - \ell(x)$. Graph the function on the same coordinate plane as you used in part (a). Identify its domain and range.

c. CHALLENGE *Explain* how you could have obtained the graph of d from the graph of ℓ using translations and reflections.

d. CHALLENGE What does the point where the graphs intersect mean in terms of the number of hours of daylight and darkness?

MIXED REVIEW

Solve the equation or proportion.

46. $y - 7 = -3$ *(p. 134)*

47. $4.5m = 49.5$ *(p. 134)*

48. $4z + 5z = -36$ *(p. 141)*

49. $5(x - 4) = 20$ *(p. 148)*

50. $3t + 4 + 5t = -4$ *(p. 148)*

51. $-5g = 3(g - 8)$ *(p. 154)*

52. $9n = 4(2n + 1)$ *(p. 154)*

53. $\frac{7}{6} = \frac{t}{42}$ *(p. 168)*

54. $\frac{5}{6} = \frac{p}{15}$ *(p. 168)*

PREVIEW
Prepare for Lesson 5.1 in Exs. 55–60.

Write the equation in slope-intercept form. Then graph the equation. *(p. 244)*

55. $x + 6y = 12$

56. $5x + y = -10$

57. $2x - 2y = 3$

58. $-2x - 3y = 21$

59. $-4x - 3y = -18$

60. $2x - y = 10$

QUIZ *for Lessons 4.6–4.7*

Given that y varies directly with x, use the specified values to write a direct variation equation that relates x and y. *(p. 253)*

1. $x = 5, y = 10$

2. $x = 4, y = 6$

3. $x = 2, y = -16$

Evaluate the function. *(p. 262)*

4. $g(x) = 6x - 5$ when $x = 4$

5. $h(x) = 14x + 7$ when $x = 2$

6. $j(x) = 0.2x + 12.2$ when $x = 244$

7. $k(x) = \frac{5}{6}x + \frac{1}{3}$ when $x = 4$

Graph the function. Compare the graph to the graph of $f(x) = x$. *(p. 262)*

8. $g(x) = -4x$

9. $h(x) = x - 2$

10. HOURLY WAGE The table shows the number of hours that you worked for each of three weeks and the amount that you were paid. What is your hourly wage? *(p. 253)*

Hours	12	16	14
Pay (dollars)	84	112	98

EXTRA PRACTICE for Lesson 4.7, p. 941

ONLINE QUIZ at classzone.com

MIXED REVIEW *of Problem Solving*

STATE TEST PRACTICE
classzone.com

Lessons 4.4–4.7

1. **MULTI-STEP PROBLEM** The amount of drink mix d (in tablespoons) that you need to add to w fluid ounces of water is given by $d = \frac{1}{4}w$.
   a. Graph the equation.
   b. Use the graph to find the amount of drink mix you need if you want to make enough drinks to serve 4 people. Assume 1 serving is 8 fluid ounces.

2. **MULTI-STEP PROBLEM** A water park charges \$25 per ticket for adults. Let s be the amount of money the park receives from adult ticket sales, and let t be the number of adult tickets sold.

   a. Write a direct variation equation that relates t and s.
   b. How much money does the park earn when 90 adult tickets are sold?
   c. The park collected \$3325 in adult ticket sales in one day. How many tickets did the park sell?

3. **SHORT RESPONSE** You and your friend are each reading an essay that is 10 pages long. You read at a rate of 1 page per minute. Your friend reads at a rate of $\frac{2}{3}$ page per minute. The models below give the number p of pages you and your friend have left to read after reading for m minutes.

   You: $p = -m + 10$

   Your friend: $p = -\frac{2}{3}m + 10$

   Graph both equations in the same coordinate plane. *Explain* how you can use the graphs to find how many more minutes it took your friend to read the essay than it took you to read the essay.

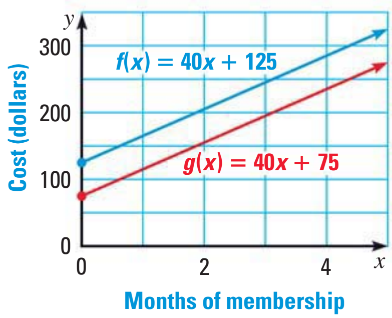
4. **OPEN-ENDED** Draw a graph that represents going to a movie theater, watching a movie, and returning home from the theater. Let the x-axis represent time and the y-axis represent your distance from home.

5. **EXTENDED RESPONSE** A central observatory averages and then reports the number of sunspots recorded by various observatories. The table shows the average number of sunspots reported by the central observatory in years since 1995.

Years since 1995	Average number of sunspots
0	17.5
2	21.0
4	93.2
6	110.9

   a. Draw a line graph of the data.
   b. During which two-year period was the increase in sunspots the greatest? Find the rate of change for this time period.
   c. During which two-year period was the increase in sunspots the least? Find the rate of change for this time period.
   d. *Explain* how you could find the overall rate of change for the time period shown.

6. **GRIDDED ANSWER** To become a member at a gym, you have to pay a sign-up fee of \$125 and a monthly fee of \$40. To attract new customers, the gym lowers the sign-up fee to \$75. The function f gives the total cost with the regular sign-up fee. The function g gives the total cost with the reduced sign-up fee. The graphs of f and g are shown. The graph of g is a vertical translation of the graph of f by how many units?



4 CHAPTER SUMMARY

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BIG IDEAS

For Your Notebook

Big Idea 1

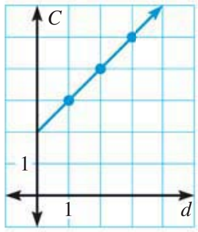
Graphing Linear Equations and Functions Using a Variety of Methods

You can graph a linear equation or function by making a table, using intercepts, or using the slope and y-intercept.

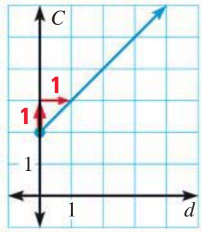
A taxi company charges a \$2 fee to pick up a customer plus \$1 per mile to drive to the customer's destination. The total cost C (in dollars) that a customer pays to travel d miles is given by $C = d + 2$. Graph this function.

Method: Make a table.

d	C
0	2
1	3
2	4
3	5



Method: Use slope and C-intercept.



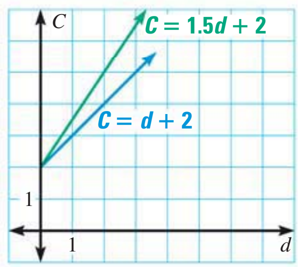
Big Idea 2

Recognizing How Changes in Linear Equations and Functions Affect Their Graphs

When you change the value of m or b in the equation $y = mx + b$, you produce an equation whose graph is related to the graph of the original equation.

Suppose the taxi company raises its rate to \$1.50 per mile. The total amount that a customer pays is given by $C = 1.5d + 2$. Graph the function.

You can see that the graphs have the same C-intercept, but different slopes.

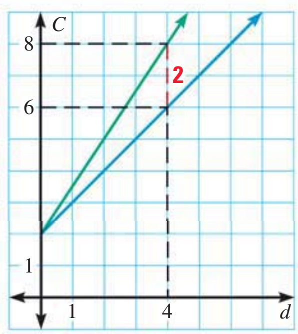


Big Idea 3

Using Graphs of Linear Equations and Functions to Solve Real-world Problems

You can use the graphs of $C = d + 2$ and $C = 1.5d + 2$ to find out how much more a customer pays to travel 4 miles at the new rate than at the old rate.

A customer pays \$2 more to travel 4 miles at the new rate.



4 CHAPTER REVIEW

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- Multi-Language Glossary
- Vocabulary practice

REVIEW KEY VOCABULARY

- quadrant, *p. 206*
- solution of an equation in two variables, *p. 215*
- graph of an equation in two variables, *p. 215*
- linear equation, *p. 216*
- standard form of a linear equation, *p. 216*
- linear function, *p. 217*
- *x*-intercept, *p. 225*
- *y*-intercept, *p. 225*
- slope, *p. 235*
- rate of change, *p. 237*
- slope-intercept form, *p. 244*
- parallel, *p. 246*
- direct variation, *p. 253*
- constant of variation, *p. 253*
- function notation, *p. 262*
- family of functions, *p. 263*
- parent linear function, *p. 263*

VOCABULARY EXERCISES

1. Copy and complete: The __?__ of a nonvertical line is the ratio of vertical change to horizontal change.

2. Copy and complete: When you write $y = 2x + 3$ as $f(x) = 2x + 3$, you use __?__.

3. **WRITING** *Describe* three different methods you could use to graph the equation $5x + 3y = 12$.

4. Tell whether the equation is written in slope-intercept form. If the equation is not in slope-intercept form, write it in slope-intercept form.

a. $3x + y = 6$ **b.** $y = 5x + 2$ **c.** $x = 4y - 1$ **d.** $y = -x + 6$

REVIEW EXAMPLES AND EXERCISES

Use the review examples and exercises below to check your understanding of the concepts you have learned in each lesson of Chapter 4.

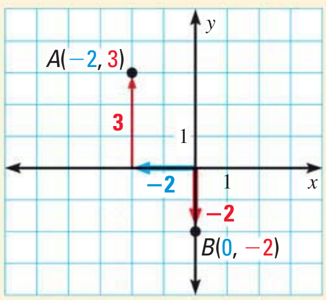
4.1 Plot Points in a Coordinate Plane *pp. 206–212*

EXAMPLE

Plot the points $A(-2, 3)$ and $B(0, -2)$ in a coordinate plane. Describe the location of the points.

Point $A(-2, 3)$: Begin at the origin and move 2 units to the left, then 3 units up. Point A is in Quadrant II.

Point $B(0, -2)$: Begin at the origin and move 2 units down. Point B is on the y-axis.



EXERCISES

EXAMPLE 2 on p. 207 for Exs. 5–7

Plot the point in a coordinate plane. *Describe* the location of the point.

5. $A(3, 4)$ **6.** $B(-5, 0)$ **7.** $C(-7, -2)$

4 CHAPTER REVIEW

4.2 Graph Linear Equations *pp. 215–221*

EXAMPLE

Graph the equation $y + 3x = 1$.

STEP 1 **Solve** the equation for y.

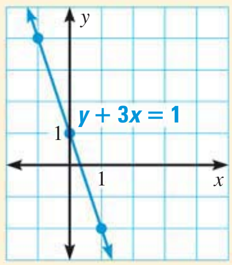
$$y + 3x = 1$$
$$y = -3x + 1$$

STEP 2 **Make** a table by choosing a few values for x and finding the values for y.

x	−1	0	1
y	4	1	−2

STEP 3 **Plot** the points.

STEP 4 **Connect** the points by drawing a line through them.



EXERCISES

EXAMPLE 2 on p. 216 for Exs. 8–10

Graph the equation.

8. $y + 5x = -5$ **9.** $2x + 3y = 9$ **10.** $2y - 14 = 4$

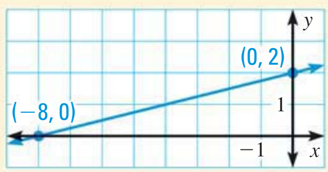
4.3 Graph Using Intercepts *pp. 225–232*

EXAMPLE

Graph the equation $-0.5x + 2y = 4$.

STEP 1 **Find** the intercepts.

$$-0.5x + 2y = 4 \qquad -0.5x + 2y = 4$$
$$-0.5x + 2(0) = 4 \qquad -0.5(0) + 2y = 4$$
$$x = -8 \leftarrow x\text{-intercept} \qquad y = 2 \leftarrow y\text{-intercept}$$



STEP 2 **Plot** the points that correspond to the intercepts: $(-8, 0)$ and $(0, 2)$.

STEP 3 **Connect** the points by drawing a line through them.

EXERCISES

EXAMPLES 2 and 4 on pp. 226–227 for Exs. 11–14

Graph the equation.

11. $-x + 5y = 15$ **12.** $4x + 4y = -16$ **13.** $2x - 6y = 18$

14. **CRAFT FAIR** You sell necklaces for \$10 and bracelets for \$5 at a craft fair. You want to earn \$50. This situation is modeled by the equation $10n + 5b = 50$ where n is the number of necklaces you sell and b is the number of bracelets you sell. Find the intercepts of the graph of the equation. Then graph the equation. Give three possibilities for the number of bracelets and necklaces that you could sell.

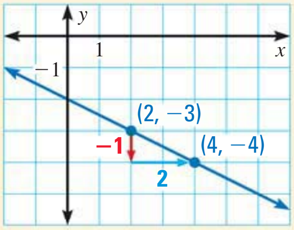
4.4 Find Slope and Rate of Change

pp. 235–242

EXAMPLE

Find the slope of the line shown.

Let $(x_1, y_1) = (2, -3)$ and $(x_2, y_2) = (4, -4)$.



$m = \dfrac{y_2 - y_1}{x_2 - x_1}$ **Write formula for slope.**

$= \dfrac{-4 - (-3)}{4 - 2}$ **Substitute values.**

$= -\dfrac{1}{2}$ **Simplify.**

EXAMPLES 1,2,3, and 4 on pp. 235–236 for Exs. 15–17

EXERCISES

Find the slope of the line that passes through the points.

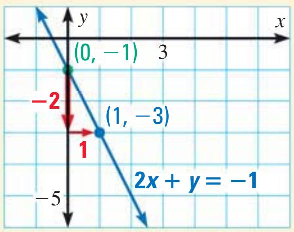
15. $(-1, 11)$ and $(2, 10)$ **16.** $(-2, 0)$ and $(4, 9)$ **17.** $(-5, 4)$ and $(1, -8)$

4.5 Graph Using Slope-Intercept Form

pp. 244–250

EXAMPLE

Graph the equation $2x + y = -1$.



STEP 1 **Rewrite** the equation in slope-intercept form.

$2x + y = -1 \rightarrow y = -2x - 1$

STEP 2 **Identify** the slope and the y-intercept.

$m = -2$ and $b = -1$

STEP 3 **Plot** the point that corresponds to the y-intercept, $(0, -1)$.

STEP 4 **Use** the slope to locate a second point on the line. Draw a line through the two points.

EXAMPLES 2 and 3 on p. 245 for Exs. 18–21

EXERCISES

Graph the equation.

18. $4x - y = 3$ **19.** $3x - 6y = 9$ **20.** $-3x + 4y - 12 = 0$

21. RUNNING One athlete can run a 60 meter race at an average rate of 7 meters per second. A second athlete can run the race at an average rate of 6 meters per second. The distance d (in meters) the athletes have left to run after t seconds is given by the following equations:

Athlete 1: $d = -7t + 60$ **Athlete 2**: $d = -6t + 60$

Graph both models in the same coordinate plane. About how many seconds faster does the first athlete finish the race than the second athlete?

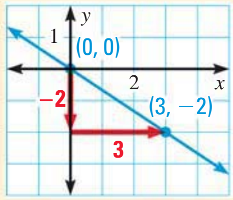
4 CHAPTER REVIEW

4.6 Model Direct Variation *pp. 253–259*

EXAMPLE

Graph the direct variation equation $y = -\frac{2}{3}x$.

Plot a point at the origin. The slope is equal to the constant of variation, $-\frac{2}{3}$. Find and plot a second point, then draw a line through the points.



EXERCISES

EXAMPLES 1, 2, and 4 on pp. 253–255 for Exs. 22–28

Tell whether the equation represents direct variation. If so, identify the constant of variation.

22. $x - y = 3$ **23.** $x + 2y = 0$ **24.** $8x - 2y = 0$

Graph the direct variation equation.

25. $y = 4x$ **26.** $-5y = 3x$ **27.** $4x + 3y = 0$

28. SNOWSTORMS The amount s (in inches) of snow that fell during a snowstorm varied directly with the duration d (in hours) of the storm. In the first 2 hours of the storm 5 inches of snow fell. Write a direct variation equation that relates d and s. How many inches of snow fell in 6 hours?

4.7 Graph Linear Functions *pp. 262–268*

EXAMPLE

Evaluate the function $f(x) = -6x + 5$ when $x = 3$.

$f(x) = -6x + 5$ **Write function.**

$f(3) = -6(3) + 5$ **Substitute 3 for *x*.**

$= -13$ **Simplify.**

EXERCISES

EXAMPLES 1 and 3 on pp. 262–263 for Exs. 29–34

Evaluate the function.

29. $g(x) = 2x - 3$ when $x = 7$ **30.** $h(x) = -\frac{1}{2}x - 7$ when $x = -6$

Graph the function. Compare the graph with the graph of $f(x) = x$.

31. $j(x) = x - 6$ **32.** $k(x) = -2.5x$ **33.** $t(x) = 2x + 1$

34. MOUNT EVEREST Mount Everest is rising at a rate of 2.4 inches per year. The number of inches that Mount Everest rises in x years is given by the function $f(x) = 2.4x$. Graph the function and identify its domain and range. Find the value of x so that $f(x) = 250$. *Explain* what the solution means in this situation.

4 CHAPTER TEST

Plot the point in a coordinate plane. *Describe* the location of the point.

1. $A(7, 1)$ **2.** $B(-4, 0)$ **3.** $C(3, -9)$

Draw the line that has the given intercepts.

4. x-intercept: 2
y-intercept: -6

5. x-intercept: -1
y-intercept: 8

6. x-intercept: -3
y-intercept: -5

Find the slope of the line that passes through the points.

7. $(2, 1)$ and $(8, 4)$ **8.** $(-2, 7)$ and $(0, -1)$ **9.** $(3, 5)$ and $(3, 14)$

Identify the slope and *y*-intercept of the line with the given equation.

10. $y = -\frac{3}{2}x - 10$ **11.** $7x + 2y = -28$ **12.** $3x - 8y = 48$

Tell whether the equation represents direct variation. If so, identify the constant of variation.

13. $x + 4y = 4$ **14.** $-\frac{1}{3}x - y = 0$ **15.** $3x - 3y = 0$

Graph the equation.

16. $x = 3$ **17.** $y + x = 6$ **18.** $2x + 8y = -32$

Evaluate the function for the given value.

19. $f(x) = -4x$ when $x = 2.5$ **20.** $g(x) = \frac{5}{2}x - 6$ when $x = -2$

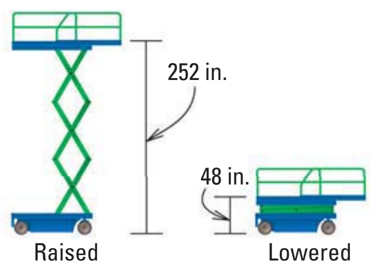
21. BUSINESS To start a dog washing business, you invest \$300 in supplies. You charge \$10 per hour for your services. Your profit P (in dollars) for working t hours is given by $P = 10t - 300$. Graph the equation. You will break even when your profit is \$0. Use the graph to find the number of hours you must work in order to break even.

22. PEDIATRICS The dose d (in milligrams) of a particular medicine that a pediatrician prescribes for a patient varies directly with the patient's mass m (in kilograms). The pediatrician recommends a dose of 150 mg of medicine for a patient whose mass is 30 kg.

a. Write a direct variation equation that relates m and d.

b. What would the dose of medicine be for a patient whose mass is 50 kg?

23. SCISSOR LIFT The scissor lift is a device that can lower and raise a platform. The maximum and minimum heights of the platform of a particular scissor lift are shown. The scissor lift can raise the platform at a rate of 3.5 inches per second. The height of the platform after t seconds is given by $h(t) = 3.5t + 48$. Graph the function and identify its domain and range.



4 ★ Standardized TEST PREPARATION

CONTEXT-BASED MULTIPLE CHOICE QUESTIONS

Some of the information you need to solve a context-based multiple choice question may appear in a table, a diagram, or a graph.

PROBLEM 1

A recipe from a box of pancake mix is shown. The number p of pancakes you can make varies directly with the number m of cups of mix you use. A full box of pancake mix contains 9 cups of mix. How many pancakes can you make when you use the full box?

(A) 63 (B) 65

(C) 126 (D) 131

2 cups pancake mix
1 cup milk
2 eggsart
Combine ingredients. Pour batter on hot greased griddle. Flip when edges are dry. Makes 14 pancakes.

Plan

INTERPRET THE INFORMATION Use the number of pancakes and the number of cups of mix given in the recipe to write a direct variation equation. Then use the equation to find the number of pancakes that you can make when you use 9 cups of mix.

Solution

STEP 1 Use the values given in the recipe to find a direct variation equation.

Because the number p of pancakes you can make varies directly with the number m of cups of mix you use, you can write the equation $p = am$. From the recipe, you know that $p = 14$ when $m = 2$.

$p = am$ **Write direct variation equation.**

$14 = a(2)$ **Substitute.**

$7 = a$ **Solve for *a*.**

So, a direct variation equation that relates p and m is $p = 7m$.

STEP 2 Substitute 9 for m in the direct variation equation and solve for p.

Use the direct variation equation to find the number of pancakes you can make when you use a full box of mix.

$p = 7m$ **Write direct variation equation.**

$p = 7(9)$ **Substitute 9 for *m*.**

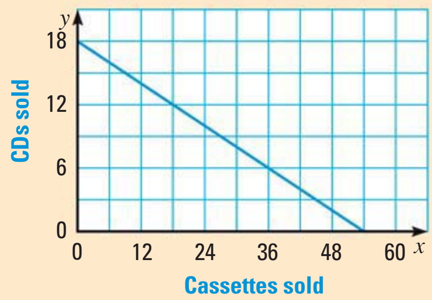
$p = 63$ **Simplify.**

You can make 63 pancakes when you use a full box of mix.

The correct answer is A. (A) (B) (C) (D)

Problem 2

At a yard sale, Jack made $54 selling cassettes for $1 each and CDs for $3 each. This situation is modeled by the equation $x + 3y = 54$ where x is the number of cassettes and y is the number of CDs that Jack sold. The graph of the equation is shown. Which is a possible combination of cassettes and CDs that Jack sold?



Ⓐ 12 cassettes, 4 CDs Ⓑ 4 cassettes, 12 CDs

Ⓒ 18 cassettes, 12 CDs Ⓓ 28.5 cassettes, 8.5 CDs

Plan

INTERPRET THE INFORMATION Each point on the line represents a solution of the equation. Identify the answer choice that describes a point on the graph shown and that makes sense in the context of the problem.

Solution

STEP 1 Write an ordered pair for each answer choice.

The answer choices correspond to the following ordered pairs.

Ⓐ (12, 4) Ⓑ (4, 12) Ⓒ (18, 12) Ⓓ (28.5, 8.5)

STEP 2 Eliminate points not on the line and points that don't make sense. Check ordered pairs not eliminated to find the solution.

You can eliminate answer choices A and B because the points do not lie on the graph shown. You can also eliminate answer choice D because only whole number solutions make sense in this situation. Check that (18, 12) is a solution of the equation.

$x + 3y = 54$ **Write original equation.**

$18 + 3(12) = 54$ **Substitute.**

$54 = 54$ ✓ **Solution checks.**

The correct answer is C. Ⓐ Ⓑ Ⓒ Ⓓ

PRACTICE

1. In Problem 2, what is the greatest number of CDs Jack could have sold?

Ⓐ 3 Ⓑ 18 Ⓒ 36 Ⓓ 54

2. The table shows the total cost for a certain number of people to ice skate at a particular rink. What is the cost per person?

Number of people	Cost (dollars)
2	10
4	20
6	30

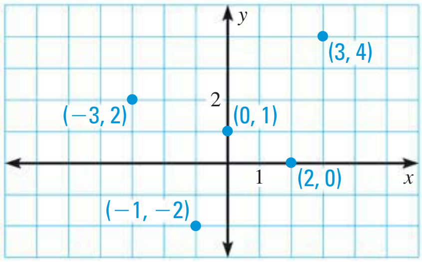
Ⓐ $.20 Ⓑ $1

Ⓒ $5 Ⓓ $10

4 ★ Standardized TEST PRACTICE

MULTIPLE CHOICE

In Exercises 1 and 2, use the graph below.



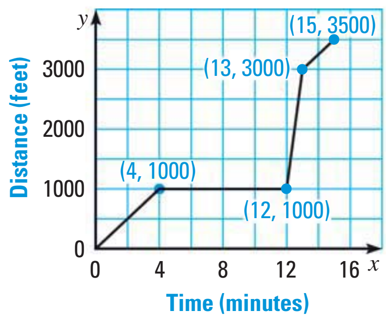
1. The graph represents a function. Which number is in the domain of the function?

   Ⓐ 22 Ⓑ −1
   Ⓒ 1 Ⓓ 4

2. The graph would no longer represent a function if which point were included?

   Ⓐ (−4, −2) Ⓑ (−2, 0)
   Ⓒ (1, 3) Ⓓ (3, −1)

In Exercises 3 and 4, use the graph below, which shows a traveler's movements through an airport to a terminal. The traveler has to walk and take a shuttle bus to get to the terminal.



3. For how many minutes does the traveler wait for the shuttle bus?

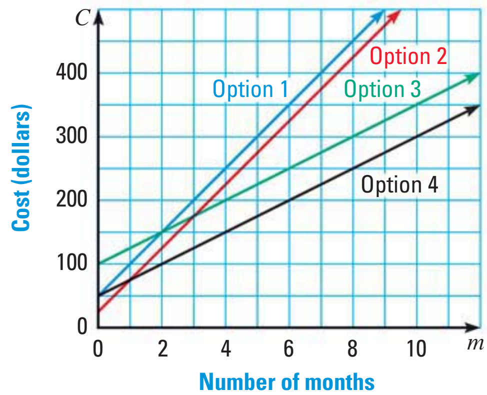
   Ⓐ 1 min Ⓑ 2 min
   Ⓒ 4 min Ⓓ 8 min

4. For about what distance does the traveler ride on the shuttle bus?

   Ⓐ 100 ft Ⓑ 100 ft
   Ⓒ 2000 ft Ⓓ 3000 ft

In Exercises 5–7, use the following information.

At a yoga studio, new members pay a sign-up fee of \$50 plus a monthly fee of \$25. The total cost C (in dollars) of a new membership is given by $C = 25m + 50$ where m is the number of months of membership. The owner of the studio is considering changing the cost of a new membership. A graph of four different options for changing the cost is shown.



5. For which option are the sign-up fee and monthly fee kept the same?

   Ⓐ Option 1 Ⓑ Option 2
   Ⓒ Option 3 Ⓓ Option 4

6. For which option is the sign-up fee kept the same and the monthly fee raised?

   Ⓐ Option 1 Ⓑ Option 2
   Ⓒ Option 3 Ⓓ Option 4

7. For which option is the monthly fee kept the same and the sign-up fee raised?

   Ⓐ Option 1 Ⓑ Option 2
   Ⓒ Option 3 Ⓓ Option 4

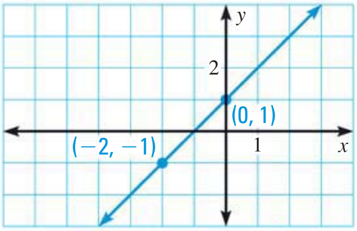
8. The table shows the cost of a therapeutic massage for a given amount of time. What is the cost per minute?

Time (minutes)	30	45	60
Cost (dollars)	42.00	63.00	84.00

   Ⓐ \$.71 Ⓑ \$1.40
   Ⓒ \$2.80 Ⓓ \$14.00

GRIDDED ANSWER

9. What is the slope of the line shown?



10. What is the y-intercept of the graph of the equation $4x + 8y = 16$?

11. What is the value of $f(x) = -1.8x - 9$ when $x = -5$?

12. The number w of cups of water varies directly with the number u of cups of uncooked rice. Use the table to find the value of the constant of variation a in the direct variation equation $w = au$.

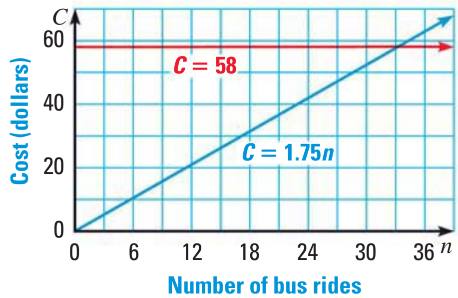
Uncooked rice, *u* (cups)	$\frac{1}{2}$	1	$1\frac{1}{2}$
Water, *w* (cups)	$\frac{3}{4}$	$1\frac{1}{2}$	$2\frac{1}{4}$

SHORT RESPONSE

13. Patricia takes a bus to and from her job. She can either pay \$1.75 each way or get a monthly bus pass for \$58 and ride the bus an unlimited number of times. The functions below give the costs C (in dollars) of riding the bus n times in one month. The graphs of the functions are shown.

Monthly pass: $C = 58$

Pay per ride: $C = 1.75n$



How many days in a month would Patricia need to take the bus to and from work to make buying a monthly pass worth the cost? *Explain*.

EXTENDED RESPONSE

14. A fog machine has a tank that holds 32 fluid ounces of fog fluid and has two settings: low and high. The low setting uses 0.2 fluid ounce of fluid per minute, and the high setting uses 0.25 fluid ounce per minute. The functions below give the amount f (in fluid ounces) of fluid left in the tank after t minutes when the machine starts with a full tank of fluid.

Low setting: $f = -0.2t + 32$ **High setting:** $f = -0.25t + 32$

a. Identify the slope and y-intercept of each function.

b. Graph each function in the same coordinate plane.

c. How much longer can the machine be run on the low setting than on the high setting? *Explain* how you found your answer.

15. At a pizzeria, a cheese pizza costs \$9. Toppings cost \$1.50 each.

a. The cost of a pizza is given by the function $f(x) = 1.5x + 9$ where x is the number of toppings. Graph the function.

b. You have \$14 and buy only a pizza. How many toppings can you get?

c. The pizzeria's owner decides to change the price of toppings to \$2 each. The new cost of a pizza is given by the function $g(x) = 2x + 9$. Graph the function in the same coordinate plane you used in part (a).

d. Can you get the same number of toppings at the new price as you did in part (b)? *Explain*.