Many real-world situations such as Olympic race times can be represented using functions. In this unit, you will learn about linear functions and equations.

Chapter 4
Graphing Relations and Functions

Chapter 5
Analyzing Linear Equations

Chapter 6
Solving Linear Inequalities

Chapter 7
Solving Systems of Linear Equations and Inequalities
The Spirit of the Games

The first Olympic Games featured only one event—a foot race. The 2004 Games will include thousands of competitors in about 300 events. In this project, you will explore how linear functions can be illustrated by the Olympics.

Log on to www.algebra1.com/webquest. Begin your WebQuest by reading the Task.

Then continue working on your WebQuest as you study Unit 2.
Graphing Relations and Functions

What You’ll Learn

- Lessons 4-1, 4-4, and 4-5 Graph ordered pairs, relations, and equations.
- Lesson 4-2 Transform figures on a coordinate plane.
- Lesson 4-3 Find the inverse of a relation.
- Lesson 4-6 Determine whether a relation is a function.
- Lessons 4-7 and 4-8 Look for patterns and write formulas for sequences.

Why It’s Important

The concept of a function is used throughout higher mathematics, from algebra to calculus. A function is a rule or a formula. You can use a function to describe real-world situations like converting between currencies. For example, if you are in Mexico, you can calculate that an item that costs 100 pesos is equivalent to about 11 U.S. dollars. You will learn how to convert different currencies in Lesson 4-4.

Key Vocabulary

- coordinate plane (p. 192)
- transformation (p. 197)
- inverse (p. 206)
- function (p. 226)
- arithmetic sequence (p. 233)
Getting Started

Prerequisite Skills  To be successful in this chapter, you’ll need to master these skills and be able to apply them in problem-solving situations. Review these skills before beginning Chapter 4.

For Lesson 4-1
Graph each set of numbers. (For review, see Lesson 2-1.)
1. \{1, 3, 5, 7\}  2. \{-3, 0, 1, 4\}  3. \{-8, -5, -2, 1\}  4. \left\{\frac{1}{2}, 1, \frac{1}{2}, 2\right\}

For Lesson 4-2
Rewrite each expression using the Distributive Property. (For review, see Lesson 1-5.)
5. \(3(7 - t)\)  6. \(-4(w + 2)\)  7. \(-5(3b - 2)\)  8. \(\frac{1}{2}(2z + 4)\)

For Lessons 4-4 and 4-5
Solve each equation for \(y\). (For review, see Lesson 3-8.)
9. \(2x + y = 1\)  10. \(x = 8 - y\)  11. \(6x - 3y = 12\)  12. \(2x + 3y = 9\)  13. \(9 - \frac{1}{2}y = 4x\)  14. \(\frac{y + 5}{3} = x + 2\)

For Lesson 4-6
Evaluate each expression if \(a = -1\), \(b = 4\), and \(c = -3\). (For review, see Lesson 2-3.)
15. \(a + b - c\)  16. \(2c - b\)  17. \(c - 3a\)  18. \(3a - 6b - 2c\)  19. \(8a + \frac{1}{2}b - 3c\)  20. \(6a + 8b + \frac{2}{3}c\)

Make this Foldable to help you organize your notes about graphing relations and functions. Begin with four sheets of grid paper.

Fold each sheet of grid paper in half from top to bottom.

Cut along fold. Staple the eight half-sheets together to form a booklet.

The top tab is 4 lines wide, the next tab is 8 lines wide, and so on.

Label each of the tabs with a lesson number.

Reading and Writing  As you read and study the chapter, use each page to write notes and to graph examples.
### Vocabulary
- axes
- origin
- coordinate plane
- y-axis
- x-axis
- x-coordinate
- y-coordinate
- quadrant
- graph

### What You’ll Learn
- Locate points on the coordinate plane.
- Graph points on a coordinate plane.

### How do archaeologists use coordinate systems?
Underwater archaeologists use a grid system to map excavation sites of sunken ships. The grid is used as a point of reference on the ocean floor. The coordinate system is also used to record the location of objects they find. Knowing the position of each object helps archaeologists reconstruct how the ship sank and where to find other artifacts.

### IDENTIFY POINTS
In mathematics, points are located in reference to two perpendicular number lines called axes.

Points in the coordinate plane are named by ordered pairs of the form \((x, y)\). The first number, or \textit{x-coordinate}, corresponds to the numbers on the x-axis. The second number, or \textit{y-coordinate}, corresponds to the numbers on the y-axis. The origin, labeled \(O\), has coordinates \((0, 0)\).

### Example 1 Name an Ordered Pair
**Write the ordered pair for point \(G\).**

- Follow along a vertical line through the point to find the \textit{x-coordinate} on the \textit{x-axis}. The \textit{x-coordinate} is \(-4\).
- Follow along a horizontal line through the point to find the \textit{y-coordinate} on the \textit{y-axis}. The \textit{y-coordinate} is \(3\).
- So, the ordered pair for point \(G\) is \((-4, 3)\). This can also be written as \(G(-4, 3)\).
The $x$-axis and $y$-axis separate the coordinate plane into four regions, called **quadrants**. Notice which quadrants contain positive and negative $x$-coordinates and which quadrants contain positive and negative $y$-coordinates. The axes are not located in any of the quadrants.

**Example 2** Identify Quadrants

Write ordered pairs for points $A$, $B$, $C$, and $D$. Name the quadrant in which each point is located.

Use a table to help find the coordinates of each point.

<table>
<thead>
<tr>
<th>Point</th>
<th>$x$-Coordinate</th>
<th>$y$-Coordinate</th>
<th>Ordered Pair</th>
<th>Quadrant</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A$</td>
<td>4</td>
<td>3</td>
<td>(4, 3)</td>
<td>I</td>
</tr>
<tr>
<td>$B$</td>
<td>2</td>
<td>0</td>
<td>(2, 0)</td>
<td>none</td>
</tr>
<tr>
<td>$C$</td>
<td>$-3$</td>
<td>$-2$</td>
<td>($-3$, $-2$)</td>
<td>III</td>
</tr>
<tr>
<td>$D$</td>
<td>1</td>
<td>$-4$</td>
<td>(1, $-4$)</td>
<td>IV</td>
</tr>
</tbody>
</table>

**GRAPH POINTS** To **graph** an ordered pair means to draw a dot at the point on the coordinate plane that corresponds to the ordered pair. This is sometimes called **plotting a point**. When graphing an ordered pair, start at the origin. The $x$-coordinate indicates how many units to move right (positive) or left (negative). The $y$-coordinate indicates how many units to move up (positive) or down (negative).

**Example 3** Graph Points

Plot each point on a coordinate plane.

a. $R(-4, 1)$
   - Start at the origin.
   - Move left 4 units since the $x$-coordinate is $-4$.
   - Move up 1 unit since the $y$-coordinate is 1.
   - Draw a dot and label it $R$.

b. $S(0, -5)$
   - Start at the origin.
   - Since the $x$-coordinate is 0, the point will be located on the $y$-axis.
   - Move down 5 units.
   - Draw a dot and label it $S$.

c. $T(3, -2)$
   - Start at the origin.
   - Move right 3 units and down 2 units.
   - Draw a dot and label it $T$.
Use a Coordinate System

GEOGRAPHY  Latitude and longitude lines form a system of coordinates to
designate locations on Earth. Latitude lines run east and west and are the first
coordinate of the ordered pairs. Longitude lines run north and south and are
the second coordinate of the ordered pairs.

a. Name the city at \((40^\circ, 105^\circ)\).
   Locate the latitude line at 40°. Follow the line until it intersects with the
   longitude line at 105°. The city is Denver.

b. Estimate the latitude and longitude of Washington, D.C.
   Locate Washington, D.C., on the map. It is close to 40° latitude and
   75° longitude. There are 5° between each line, so a good estimate is
   39° for the latitude and 77° for the longitude.

Check for Understanding

Concept Check  1. Draw a coordinate plane. Label the origin, \(x\)-axis, \(y\)-axis, and the quadrants.
2. Explain why \((-1, 4)\) does not name the same point as \((4, -1)\).
3. OPEN ENDED  Give the coordinates of a point for each quadrant in the
   coordinate plane.

Guided Practice  Write the ordered pair for each point shown at
the right. Name the quadrant in which the point
is located.

4. \(E\)  5. \(F\)  6. \(G\)  7. \(H\)

Plot each point on a coordinate plane.

8. \(J(2, 5)\)  9. \(K(-1, 4)\)  10. \(L(0, -3)\)
11. \(M(-2, -2)\)

Application  12. ARCHITECTURE  Chun Wei has sketched the
   southern view of a building. If \(A\) is located on
   a coordinate system at \((-40, 10)\), locate the
   coordinates of the other vertices.
Write the ordered pair for each point shown at the right. Name the quadrant in which the point is located.

15. Q 16. R
17. S 18. T
19. U 20. V
21. W 22. Z

23. Write the ordered pair that describes a point 12 units down from and 7 units to the right of the origin.
24. Write the ordered pair for a point that is 9 units to the left of the origin and lies on the x-axis.

Plot each point on a coordinate plane.

25. A(3, 5) 26. B(−2, 2) 27. C(4, −2) 28. D(0, −1)
33. I(3, 1) 34. J(−1, −3) 35. K(−4, 0) 36. L(2, −4)

GEOGRAPHY For Exercises 37 and 38, use the map on page 194.

37. Name two cities that have approximately the same latitude.
38. Name two cities that have approximately the same longitude.

ARCHAEOLOGY The diagram at the right shows the positions of artifacts found on the ocean floor. Write the coordinates of the location for each object: coins, plate, goblet, and vase.

For Exercises 37 and 38, use the map at the left.

On many maps, letters and numbers are used to define a region or sector. For example, Palmer Field is located in sector E2. Rogelio is a guide for new students at the University of Michigan. He has selected campus landmarks to show the students.

40. In what sector is the Undergraduate Library?
41. In what sector are most of the science buildings?
42. Which street goes from sector (A, 2) to (D, 2)?
43. Name the sectors that have bus stops.

CRITICAL THINKING Describe the possible locations, in terms of quadrants or axes, for the graph of (x, y) given each condition.

a. xy > 0  b. xy < 0  c. xy = 0

www.algebra1.com/self_check_quiz
45. **Writing in Math** Answer the question that was posed at the beginning of the lesson.

**How do archaeologists use coordinate systems?**

Include the following in your answer:
- an explanation of how dividing an excavation site into sectors can be helpful in excavating a site, and
- a reason why recording the exact location of an artifact is important.

For Exercises 46 and 47, refer to the figure at the right.

46. **ABCD** is a rectangle with its center at the origin. If the coordinates of vertex B are (3, 2), what are the coordinates of vertex A?

A (−3, −2)  B (3, −2)  C (−3, 2)  D (3, 2)

47. What is the length of \(AD\)?

A 6 units  B 4 units  C 5 units  D 3 units

The **midpoint** of a line segment is the point that lies exactly halfway between the two endpoints. The midpoint of a line segment whose endpoints are at \((a, b)\) and \((c, d)\) is at \(\left(\frac{a + c}{2}, \frac{b + d}{2}\right)\). Find the midpoint of each line segment whose endpoints are given.

48. \((7, 1)\) and \((-3, 1)\)  49. \((5, -2)\) and \((9, -8)\)  50. \((-4, 4)\) and \((4, -4)\)

**Extending the Lesson**

**Standardized Test Practice**

**Maintain Your Skills**

**Mixed Review**

51. **Airplanes** At 1:30 P.M., an airplane leaves Tucson for Baltimore, a distance of 2240 miles. The plane flies at 280 miles per hour. A second airplane leaves Tucson at 2:15 P.M. and is scheduled to land in Baltimore 15 minutes before the first airplane. At what rate must the second airplane travel to arrive on schedule? (Lesson 3-9)

Solve each equation or formula for the variable specified. (Lesson 3-8)

52. \(3x + b = 2x + 5\) for \(x\)  53. \(10c = 2(2d + 3c)\) for \(d\)

54. \(6w - 3h = b\) for \(h\)  55. \(\frac{3(a - t)}{4} = 2t\) for \(t\)

Find each square root. Round to the nearest hundredth if necessary. (Lesson 2-7)

56. \(-\sqrt{81}\)  57. \(\sqrt{63}\)  58. \(\sqrt{180}\)  59. \(-\sqrt{256}\)

Evaluate each expression. (Lesson 2-1)

60. \(52 + |18 - 7|\)  61. \(|81 - 47| + 17\)  62. \(42 - |60 - 74|\)

63. \(36 - |15 - 21|\)  64. \(|10 - 16 + 27|\)  65. \(|38 - 65 - 21|\)

**Getting Ready for the Next Lesson**

**Prerequisite Skill** Rewrite each expression using the Distributive Property. Then simplify. (To review the Distributive Property, see Lesson 1-5.)

66. \(4(x + y)\)  67. \(-1(x + 3)\)  68. \(3(1 - 6y)\)

69. \(-3(2x - 5)\)  70. \(\frac{1}{3}(2x + 6y)\)  71. \(\frac{1}{4}(5x - 2y)\)
Transformations on the Coordinate Plane

**What You’ll Learn**
- Transform figures by using reflections, translations, dilations, and rotations.
- Transform figures on a coordinate plane by using reflections, translations, dilations, and rotations.

**Vocabulary**
- transformation
- preimage
- image
- reflection
- translation
- dilation
- rotation

**How are transformations used in computer graphics?**
Computer programs can create movement that mimic real-life situations. A new CD-ROM-based flight simulator replicates an actual flight experience so closely that the U.S. Navy is using it for all of their student aviators. The movements of the on-screen graphics are accomplished by using mathematical transformations.

**TRANSFORM FIGURES** Transformations are movements of geometric figures. The **preimage** is the position of the figure before the transformation, and the **image** is the position of the figure after the transformation.

- **reflection**
  - a figure is flipped over a line

- **translation**
  - a figure is slid in any direction

- **dilation**
  - a figure is enlarged or reduced

- **rotation**
  - a figure is turned around a point

**Example 1 Identify Transformations**
Identify each transformation as a reflection, translation, dilation, or rotation.

a. The figure has been turned around a point. This is a rotation.

b. The figure has been flipped over a line. This is a reflection.

c. The figure has been increased in size. This is a dilation.

d. The figure has been shifted horizontally to the right. This is a translation.
**Key Concept Transformations on the Coordinate Plane**

<table>
<thead>
<tr>
<th>Name</th>
<th>Words</th>
<th>Symbols</th>
<th>Model</th>
</tr>
</thead>
</table>
| **Reflection** | To reflect a point over the x-axis, multiply the y-coordinate by \(-1\).  
To reflect a point over the y-axis, multiply the x-coordinate by \(-1\). | reflection over x-axis: \((x, y) \rightarrow (x, -y)\)  
reflection over y-axis: \((x, y) \rightarrow (-x, y)\) | ![Reflection Diagram] |
| **Translation** | To translate a point by an ordered pair \((a, b)\), add \(a\) to the x-coordinate and \(b\) to the y-coordinate. | \((x, y) \rightarrow (x + a, y + b)\) | ![Translation Diagram] |
| **Dilation** | To dilate a figure by a scale factor \(k\), multiply both coordinates by \(k\).  
If \(k > 1\), the figure is enlarged.  
If \(0 < k < 1\), the figure is reduced. | \((x, y) \rightarrow (kx, ky)\) | ![Dilation Diagram] |
| **Rotation** | To rotate a figure 90° counterclockwise about the origin, switch the coordinates of each point and then multiply the new first coordinate by \(-1\).  
To rotate a figure 180° about the origin, multiply both coordinates of each point by \(-1\). | 90° rotation: \((x, y) \rightarrow (-y, x)\)  
180° rotation: \((x, y) \rightarrow (-x, -y)\) | ![Rotation Diagram] |

---

**Example 2 Reflection**

A parallelogram has vertices \(A(-4, 3), B(1, 3), C(0, 1),\) and \(D(-5, 1)\).

a. Parallelogram \(ABCD\) is reflected over the \(x\)-axis. Find the coordinates of the vertices of the image.

To reflect the figure over the \(x\)-axis, multiply each \(y\)-coordinate by \(-1\).

\[
\begin{align*}
A(-4, 3) & \rightarrow A'(-4, -3) \\
B(1, 3) & \rightarrow B'(1, -3) \\
C(0, 1) & \rightarrow C'(0, -1) \\
D(-5, 1) & \rightarrow D'(-5, -1)
\end{align*}
\]

The coordinates of the vertices of the image are \(A'(-4, -3), B'(1, -3), C'(0, -1),\) and \(D'(-5, -1)\).
b. Graph parallelogram $ABCD$ and its image $A'B'C'D'$.

Graph each vertex of the parallelogram $ABCD$. Connect the points.
Graph each vertex of the reflected image $A'B'C'D'$. Connect the points.

Example 3 Translation

Triangle $ABC$ has vertices $A(-2, 3), B(4, 0)$, and $C(2, -5)$.

a. Find the coordinates of the vertices of the image if it is translated 3 units to the left and 2 units down.

To translate the triangle 3 units to the left, add $-3$ to the $x$-coordinate of each vertex. To translate the triangle 2 units down, add $-2$ to the $y$-coordinate of each vertex.

$$(x, y) \rightarrow (x - 3, y - 2)$$

$A(-2, 3) \rightarrow A'(-2 - 3, 3 - 2) \rightarrow A'(-5, 1)$

$B(4, 0) \rightarrow B'(4 - 3, 0 - 2) \rightarrow B'(1, -2)$

$C(2, -5) \rightarrow C'(2 - 3, -5 - 2) \rightarrow C'(-1, -7)$

The coordinates of the vertices of the image are $A'(-5, 1), B'(1, -2), and C'(-1, -7)$.

b. Graph triangle $ABC$ and its image.

The preimage is $\Delta ABC$.
The translated image is $\Delta A'B'C'$.

Example 4 Dilation

A trapezoid has vertices $L(-4, 1), M(1, 4), N(7, 0), and P(-3, -6)$.

a. Find the coordinates of the dilated trapezoid $L'M'N'P'$ if the scale factor is $\frac{3}{4}$.

To dilate the figure multiply the coordinates of each vertex by $\frac{3}{4}$.

$$(x, y) \rightarrow \left(\frac{3}{4}x, \frac{3}{4}y\right)$$

$L(-4, 1) \rightarrow L'(\frac{3}{4} \cdot (-4), \frac{3}{4} \cdot 1) \rightarrow L'(-3, \frac{3}{4})$

$M(1, 4) \rightarrow M'(\frac{3}{4} \cdot 1, \frac{3}{4} \cdot 4) \rightarrow M'(\frac{3}{4}, 3)$

$N(7, 0) \rightarrow N'(\frac{3}{4} \cdot 7, \frac{3}{4} \cdot 0) \rightarrow N'(\frac{3}{4}, 0)$

$P(-3, -6) \rightarrow P'(\frac{3}{4} \cdot (-3), \frac{3}{4} \cdot (-6)) \rightarrow P'(-\frac{3}{4}, -\frac{3}{2})$

The coordinates of the vertices of the image are $L'(-3, \frac{3}{4}), M'(\frac{3}{4}, 3)$,

$(continued on the next page)
b. Graph the preimage and its image.
The preimage is trapezoid $LMNP$.
The image is trapezoid $L'M'N'P'$.
Notice that the image has sides that are three-fourths the length of the sides of the original figure.

**Example 5 Rotation**

Triangle $XYZ$ has vertices $X(1, 5)$, $Y(5, 2)$, and $Z(−1, 2)$.

a. Find the coordinates of the image of $\triangle XYZ$ after it is rotated $90^\circ$ counterclockwise about the origin.

To find the coordinates of the vertices after a $90^\circ$ rotation, switch the coordinates of each point and then multiply the new first coordinate by $−1$.

$(x, y) \rightarrow (−y, x)$

$X(1, 5) \rightarrow X'(−5, 1)$
$Y(5, 2) \rightarrow Y'(−2, 5)$
$Z(−1, 2) \rightarrow Z'(−2, −1)$

b. Graph the preimage and its image.
The image is $\triangle XYZ$.
The rotated image is $\triangle X'Y'Z'$.

---

**Check for Understanding**

**Concept Check**

1. Compare and contrast the size, shape, and orientation of a preimage and an image for each type of transformation.

2. **OPEN ENDED** Draw a figure on the coordinate plane. Then show a dilation of the object that is an enlargement and a dilation of the object that is a reduction.

**Guided Practice**

Identify each transformation as a reflection, translation, dilation, or rotation.

3. Find the coordinates of the vertices of each figure after the given transformation is performed. Then graph the preimage and its image.
4. [Diagram of a figure and its transformation]

5. triangle $PQR$ with $P(1, 2)$, $Q(4, 4)$, and $R(2, −3)$ reflected over the $x$-axis
6. quadrilateral $ABCD$ with $A(4, 2)$, $B(4, −2)$, $C(−1, −3)$, and $D(−3, 2)$ translated 3 units up
7. parallelogram $EFGH$ with $E(−1, 4)$, $F(5, −1)$, $G(2, −4)$, and $H(−4, 1)$ dilated by a scale factor of 2
8. triangle $JKL$ with $J(0, 0)$, $K(−2, −5)$, and $L(−4, 5)$ rotated $90^\circ$ counterclockwise about the origin
Application

NAVIGATION For Exercises 9 and 10, use the following information.
A ship was heading on a chartered route when it was blown off course by a storm. The ship is now ten miles west and seven miles south of its original destination.

9. Using a coordinate grid, make a drawing to show the original destination A and the current position B of the ship.

10. Using coordinates \((x, y)\) to represent the original destination of the ship, write an expression to show its current location.

Practice and Apply

Identify each transformation as a reflection, translation, dilation, or rotation.

11. 12.


15. 16.

For Exercises 17–26, complete parts a and b.

a. Find the coordinates of the vertices of each figure after the given transformation is performed.

b. Graph the preimage and its image.

17. triangle \(RST\) with \(R(2, 0)\), \(S(-2, -3)\), and \(T(-2, 3)\) reflected over the \(y\)-axis

18. trapezoid \(ABCD\) with \(A(2, 3)\), \(B(5, 3)\), \(C(6, 1)\), and \(D(-2, 1)\) reflected over the \(x\)-axis

19. quadrilateral \(RSTU\) with \(R(-6, 3)\), \(S(-4, 2)\), \(T(-1, 5)\), and \(U(-3, 7)\) translated 8 units right

20. parallelogram \(MNOP\) with \(M(-6, 0)\), \(N(-4, 3)\), \(O(-1, 3)\), and \(P(-3, 0)\) translated 3 units right and 2 units down

21. trapezoid \(JKLM\) with \(J(-4, 2)\), \(K(-2, 4)\), \(L(4, 4)\), and \(M(-4, -4)\) dilated by a scale factor of \(\frac{1}{2}\)

22. square \(ABCD\) with \(A(-2, 1)\), \(B(2, 2)\), \(C(3, -2)\), and \(D(-1, -3)\) dilated by a scale factor of 3

23. triangle \(FGH\) with \(F(-3, 2)\), \(G(2, 5)\), and \(H(6, 3)\) rotated 180° about the origin

24. quadrilateral \(TUVW\) with \(T(-4, 2)\), \(U(-2, 4)\), \(V(0, 2)\), and \(W(-2, -4)\) rotated 90° counterclockwise about the origin

25. parallelogram \(WXYZ\) with \(W(-1, 2)\), \(X(3, 2)\), \(Y(0, -4)\), and \(Z(-4, -4)\) reflected over the \(y\)-axis, then rotated 180° about the origin

26. pentagon \(PQRST\) with \(P(0, 5)\), \(Q(3, 4)\), \(R(2, 1)\), \(S(-2, 1)\), and \(T(-3, 4)\) reflected over the \(x\)-axis, then translated 2 units left and 1 unit up
For Exercises 27–29, use the diagram at the right.
An animator places an arrow representing an airplane on a coordinate grid. She wants to move the arrow 2 units right and then reflect it across the x-axis.

27. Write the coordinates for the vertices of the arrow.

28. Find the coordinates of the final position of the arrow.

29. Graph the image.

30. Trapezoid $JKLM$ with $J(-6, 0)$, $K(-1, 5)$, $L(-1, 1)$, and $M(-3, -1)$ is translated to $J'K'L'M'$ with $J'(-3, -2)$, $K'(2, 3)$, $L'(2, -1)$, $M'(0, -3)$. Describe this translation.

31. Triangle $QRS$ with vertices $Q(-2, 6)$, $R(8, 0)$, and $S(6, 4)$ is dilated. If the image $Q'R'S'$ has vertices $Q'(-1, 3)$, $R'(4, 0)$, and $S'(3, 2)$, what is the scale factor?

32. Describe the transformation of parallelogram $WXYZ$ with $W(-5, 3)$, $X(-2, 5)$, $Y(0, 3)$, and $Z(-3, 1)$ if the coordinates of its image are $W'(5, 3)$, $X'(2, 5)$, $Y'(0, 3)$, and $Z'(3, 1)$.

33. Describe the transformation of triangle $XYZ$ with $X(2, -1)$, $Y(-5, 3)$, and $Z(4, 0)$ if the coordinates of its image are $X'(1, 2)$, $Y'(-3, -5)$, and $Z'(0, 4)$.

For Exercises 34–36, use the following information.
Soto wants to enlarge a digital photograph that is 1800 pixels wide and 1600 pixels high (1800 $\times$ 1600) by a scale factor of $\frac{3}{2}$.

34. What will be the dimensions of the new digital photograph?

35. Use a coordinate grid to draw a picture representing the 1800 $\times$ 1600 digital photograph. Place one corner of the photograph at the origin and write the coordinates of the other three vertices.

36. Draw the enlarged photograph and write its coordinates.

For Exercises 37 and 38, use the following information.
On grid paper, draw a regular octagon like the one shown.

37. Reflect the octagon over each of its sides. Describe the pattern that results.

38. Could this same pattern be drawn using any of the other transformations? If so, which kind?

39. CRITICAL THINKING Make a conjecture about the coordinates of a point $(x, y)$ that has been rotated 90° clockwise about the origin.

40. CRITICAL THINKING Determine whether the following statement is sometimes, always, or never true.

A reflection over the x-axis followed by a reflection over the y-axis gives the same result as a rotation of 180°.
41. **WRITING IN MATH** Answer the question that was posed at the beginning of the lesson.

**How are transformations used in computer graphics?**

Include the following in your answer:
- examples of movements that could be simulated by transformations, and
- types of other industries that might use transformations in computer graphics to simulate movement.

42. The coordinates of the vertices of quadrilateral QRST are Q(−2, 4), R(3, 7), S(4, −2), and T(−5, −3). If the quadrilateral is moved up 3 units and right 1 unit, which point below has the correct coordinates?

- **A** Q'(1, 5)
- **B** R'(4, 4)
- **C** S'(5, 1)
- **D** T'(−6, 0)

43. \(x = \frac{2}{3} \) of \(y\) and \(y = \frac{1}{4} \) of \(z\). If \(x = 14\), then \(z =\)

- **A** 48
- **B** 72
- **C** 84
- **D** 96

44. Graph the image of each figure after a reflection over the graph of the given equation. Find the coordinates of the vertices.

- **44.** \(x = 0\)
- **45.** \(y = −3\)
- **46.** \(y = x\)

47. **CHEMISTRY** Jamaal needs a 25% solution of nitric acid. He has 20 milliliters of a 30% solution. How many milliliters of a 15% solution should he add to obtain the required 25% solution? (Lesson 3-9)

53. Two dice are rolled and their sum is recorded. Find each probability. (Lesson 2-6)

- **54.** \(P(\text{sum is less than 9})\)
- **55.** \(P(\text{sum is greater than 10})\)
- **56.** \(P(\text{sum is less than 7})\)
- **57.** \(P(\text{sum is greater than 4})\)

58. **PREREQUISITE SKILL** Write a set of ordered pairs that represents the data in the table. (To review ordered pairs, see Lesson 1-8.)

<table>
<thead>
<tr>
<th>Number of toppings</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of large pizza ($)</td>
<td>9.95</td>
<td>11.45</td>
<td>12.95</td>
<td>14.45</td>
<td>15.95</td>
<td>17.45</td>
</tr>
</tbody>
</table>

59. | Time (minutes) | 0 | 5 | 10 | 15 | 20 | 25 | 30 |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature of boiled water as it cools (°C)</td>
<td>100</td>
<td>90</td>
<td>81</td>
<td>73</td>
<td>66</td>
<td>60</td>
<td>55</td>
</tr>
</tbody>
</table>

Lesson 4-2 Transformations on the Coordinate Plane 203
Graphs of Relations

You can represent a relation as a graph using a TI-83 Plus graphing calculator.

Graph the relation \{ (3, 7), (-8, 12), (-5, 7), (11, -1) \}.

Step 1 Enter the data.
- Enter the x-coordinates in L1 and the y-coordinates in L2.

**KEYSTROKES:**
```
STAT ENTER 3 ENTER −8
ENTER −5 ENTER 11 ENTER □ 7 ENTER
12 ENTER 7 ENTER −1 ENTER
```

Step 2 Format the graph.
- Turn on the statistical plot.

**KEYSTROKES:**
```
2nd STAT PLOT ENTER ENTER
```
- Select the scatter plot, L1 as the Xlist and L2 as the Ylist.

**KEYSTROKES:**
```
2nd ENTER □ ENTER 2nd L1
```

Step 3 Choose the viewing window.
- Be sure you can see all of the points.

\([-10, 15]\) scl: 1 by \([-5, 15]\) scl: 1

**KEYSTROKES:**
```
WINDOW −10 ENTER 15 ENTER
1 ENTER −5 ENTER 15 ENTER 1
```

Step 4 Graph the relation.
- Display the graph.

**KEYSTROKES:**
```
GRAPH
```

Exercises

Graph each relation. Sketch the result.

1. \{ (10, 10), (0, −6), (4, 7), (5, −2) \}
2. \{ (−4, 1), (3, −5), (4, 5), (−5, 1) \}
3. \{ (12, 15), (10, −16), (11, 7), (−14, −19) \}
4. \{ (45, 10), (23, 18), (22, 26), (35, 26) \}

5. **MAKE A CONJECTURE** How are the values of the domain and range used to determine the scale of the viewing window?

www.algebra1.com/other_calculator_keystrokes
What You’ll Learn

- Represent relations as sets of ordered pairs, tables, mappings, and graphs.
- Find the inverse of a relation.

Vocabulary

- mapping
- inverse

How can relations be used to represent baseball statistics?

Ken Griffey, Jr.’s, batting statistics for home runs and strikeouts can be represented as a set of ordered pairs. These statistics are shown in the table at the right, where the first coordinates represent the number of home runs and the second coordinates represent the number of strikeouts. You can plot the ordered pairs on a graph to look for patterns in the distribution of the points.

REPRESENT RELATIONS  Recall that a relation is a set of ordered pairs. A relation can be represented by a set of ordered pairs, a table, a graph, or a mapping. A mapping illustrates how each element of the domain is paired with an element in the range. Study the different representations of the same relation below.

<table>
<thead>
<tr>
<th>Ordered Pairs</th>
<th>Table</th>
<th>Graph</th>
<th>Mapping</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1, 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(−2, 4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0, −3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>x</td>
<td>y</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>−2</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>−3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example 1  Represent a Relation

a. Express the relation {(3, 2), (−1, 4), (0, −3), (−3, 4), (−2, −2)} as a table, a graph, and a mapping.

Table

List the set of x-coordinates in the first column and the corresponding y-coordinates in the second column.

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>−1</td>
<td>4</td>
</tr>
<tr>
<td>0</td>
<td>−3</td>
</tr>
<tr>
<td>−3</td>
<td>4</td>
</tr>
<tr>
<td>−2</td>
<td>−2</td>
</tr>
</tbody>
</table>

Graph

Graph each ordered pair on a coordinate plane.
Mapping

List the \( x \) values in set \( X \) and the \( y \) values in set \( Y \). Draw an arrow from each \( x \) value in \( X \) to the corresponding \( y \) value in \( Y \).

b. Determine the domain and range.

The domain for this relation is \{-3, -2, -1, 0, 3\}.

The range is \{-3, -2, 2, 4\}.

When graphing relations that represent real-life situations, you may need to select values for the \( x \)- or \( y \)-axis that do not begin with 0 and do not have units of 1.

**Example 2** Use a Relation

**Bald Eagles** In 1990, New York purchased 12,000 acres for the protection of bald eagles. The table shows the number of eagles observed in New York during the annual mid-winter bald eagle survey from 1993 to 2000.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Eagles</td>
<td>102</td>
<td>116</td>
<td>144</td>
<td>174</td>
<td>175</td>
<td>177</td>
<td>244</td>
<td>350</td>
</tr>
</tbody>
</table>

Source: New York Department of Environmental Conservation

a. Determine the domain and range of the relation.


The range is \{102, 116, 144, 174, 175, 177, 244, 350\}.

b. Graph the data.

- The values of the \( x \)-axis need to go from 1993 to 2000. It is not practical to begin the scale at 0. Begin at 1992 and extend to 2001 to include all of the data. The units can be 1 unit per grid square.

- The values on the \( y \)-axis need to go from 102 to 350. In this case, it is possible to begin the scale at 0. Begin at 0 and extend to 400. You can use units of 50.

c. What conclusions might you make from the graph of the data?

The number of eagles has increased each year. This may be due to the efforts of those who are protecting the eagles in New York.

**Inverse Relations** The inverse of any relation is obtained by switching the coordinates in each ordered pair.

**Key Concept** **Inverse of a Relation**

Relation \( Q \) is the inverse of relation \( S \) if and only if for every ordered pair \((a, b)\) in \( S \), there is an ordered pair \((b, a)\) in \( Q \).
Relations and Inverses

1. Graph the relation \(\{(3, 4), (-3, 2), (6, 7), (5, -1)\}\) on grid paper using a colored pencil. Connect the points in order using the same colored pencil.

2. Use a different colored pencil to graph the inverse of the relation, connecting the points in order.

3. Fold the grid paper through the origin so that the positive \(y\)-axis lies on top of the positive \(x\)-axis. Hold the paper up to a light so that you can see all of the points you graphed.

Analyze

1. What do you notice about the location of the points you graphed when you looked at the folded paper?
2. Unfold the paper. Describe the transformation of each point and its inverse.
3. What do you think are the ordered pairs that represent the points on the fold line? Describe these in terms of \(x\) and \(y\).

Make a Conjecture

4. How could you graph the inverse of a function without writing ordered pairs first?
1. Describe the different ways a relation can be represented.

2. OPEN ENDED Give an example of a set of ordered pairs that has five elements in its domain and four elements in its range.

3. State the relationship between the domain and range of a relation and the domain and range of its inverse.

Express each relation as a table, a graph, and a mapping. Then determine the domain and range.

4. \{\{(5, -2), (8, 3), (-7, 1)\}\}
5. \{\{(6, 4), (3, -3), (-1, 9), (5, -3)\}\}
6. \{\{(7, 1), (3, 0), (-2, 5)\}\}
7. \{\{(-4, 8), (-1, 9), (-4, 7), (6, 9)\}\}

Express the relation shown in each table, mapping, or graph as a set of ordered pairs. Then write the inverse of the relation.

8. \[
\begin{array}{c|c}
 x & y \\
 \hline
 3 & -2 \\
 -6 & 7 \\
 4 & 3 \\
 -6 & 5 \\
\end{array}
\]

9. \[
\begin{array}{c|c}
 x & y \\
 \hline
 -4 & 9 \\
 2 & 5 \\
 -2 & -2 \\
 11 & 12 \\
\end{array}
\]

10. \[
\begin{array}{c}
 x \\
 3 \\
 5 \\
 7 \\
\end{array}
\begin{array}{c}
 y \\
 0 \\
 -2 \\
 -4 \\
\end{array}
\]

11. \[
\begin{array}{c}
 x \\
 2 \\
 3 \\
 4 \\
 5 \\
\end{array}
\begin{array}{c}
 y \\
 2 \\
 3 \\
 4 \\
 5 \\
\end{array}
\begin{array}{c}
 O \\
 6 \\
 7 \\
 8 \\
\end{array}
\]

12. \[
\begin{array}{c|c|c|c|c}
 x & y \\
 \hline
 0 & \star \\
 5 & \star \\
 10 & \star \\
 15 & \star \\
 20 & \star \\
\end{array}
\]

13. \[
\begin{array}{c|c|c|c}
 x & y \\
 \hline
 0 & \star \\
 5 & \star \\
 10 & \star \\
 15 & \star \\
 20 & \star \\
\end{array}
\]

Application TECHNOLOGY For Exercises 14–17, use the graph of the average number of students per computer in U.S. public schools.

14. Name three ordered pairs from the graph.

15. Determine the domain of the relation.

16. Estimate the least value and the greatest value in the range.

17. What conclusions can you make from the graph of the data?

Online Research Data Update What is the average number of students per computer in your state? Visit www.algebra1.com/data_update to learn more.

Source: Quality Education Data
Express each relation as a table, a graph, and a mapping. Then determine the domain and range.

18. \{ (4, 3), (1, -7), (1, 3), (2, 9) \}
19. \{ (5, 2), (-5, 0), (6, 4), (2, 7) \}
20. \{ (0, 0), (6, -1), (5, 6), (4, 2) \}
21. \{ (3, 8), (3, 7), (2, -9), (1, -9) \}
22. \{ (4, -2), (3, 4), (1, -2), (6, 4) \}
23. \{ (0, 2), (-5, 1), (0, 6), (-1, 9) \}
24. \{ (3, 4), (4, 3), (2, 2), (5, -4), (-4, 5) \}
25. \{ (7, 6), (3, 4), (4, 5), (-2, 6), (-3, 2) \}

Express the relation shown in each table, mapping, or graph as a set of ordered pairs. Then write the inverse of the relation.

26. 
\[
\begin{array}{c|c}
 x & y \\
\hline
 1 & 2 \\
 3 & 4 \\
 5 & 6 \\
 7 & 8 \\
\end{array}
\]

27. 
\[
\begin{array}{c|c}
 x & y \\
\hline
 0 & -3 \\
 -5 & 2 \\
 4 & 7 \\
 -3 & 2 \\
\end{array}
\]

28. 
\[
\begin{array}{c|c}
 x & y \\
\hline
 6 & -2 \\
 4 & 3 \\
 3 & -5 \\
 1 & 7 \\
\end{array}
\]

29. 
\[
\begin{array}{c|c}
 x & y \\
\hline
 -8 & 1 \\
 -1 & 4 \\
 0 & 6 \\
 5 & 8 \\
\end{array}
\]

30. 
\[
\begin{array}{c|c}
 x & y \\
\hline
 1 & 16.5 \\
 1.75 & 28.3 \\
 2.5 & 49.1 \\
 3.25 & 87.6 \\
 4 & 103.4 \\
\end{array}
\]

31. 
\[
\begin{array}{c|c}
 x & y \\
\hline
 -3 & 2 \\
 5 & 6 \\
 8 & 11 \\
 11 & 14.5 \\
\end{array}
\]

32. 
\[
\begin{array}{c|c}
 x & y \\
\hline
 0 & 0 \\
 4 & 7 \\
 8 & 10.5 \\
 12 & 13 \\
 16 & 14.5 \\
\end{array}
\]

33. 
\[
\begin{array}{c|c}
 x & y \\
\hline
 1 & 16.5 \\
 1.75 & 28.3 \\
 2.5 & 49.1 \\
 3.25 & 87.6 \\
 4 & 103.4 \\
\end{array}
\]

34. 
\[
\begin{array}{c|c}
 x & y \\
\hline
 -3 & 2 \\
 5 & 6 \\
 8 & 11 \\
 11 & 14.5 \\
\end{array}
\]

35. 
\[
\begin{array}{c|c}
 x & y \\
\hline
 2 & 0 \\
 3 & 4 \\
 5 & 8 \\
 -7 & 7 \\
\end{array}
\]

36. 
\[
\begin{array}{c|c}
 x & y \\
\hline
 1 & 16.5 \\
 1.75 & 28.3 \\
 2.5 & 49.1 \\
 3.25 & 87.6 \\
 4 & 103.4 \\
\end{array}
\]

37. 
\[
\begin{array}{c|c}
 x & y \\
\hline
 -3 & 2 \\
 5 & 6 \\
 8 & 11 \\
 11 & 14.5 \\
\end{array}
\]

**COOKING** For Exercises 38–40, use the table that shows the boiling point of water at various altitudes. Many recipes have different cooking times for high altitudes. This is due to the fact that water boils at a lower temperature in higher altitudes.

38. Graph the relation.
39. Write the inverse as a set of ordered pairs.
40. How could you estimate your altitude by finding the boiling point of water at your location?

<table>
<thead>
<tr>
<th>Altitude (feet)</th>
<th>Boiling Point of Water (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>212.0</td>
</tr>
<tr>
<td>1000</td>
<td>210.2</td>
</tr>
<tr>
<td>2000</td>
<td>208.4</td>
</tr>
<tr>
<td>3000</td>
<td>206.5</td>
</tr>
<tr>
<td>5000</td>
<td>201.9</td>
</tr>
<tr>
<td>10,000</td>
<td>193.7</td>
</tr>
</tbody>
</table>

*Source: Stevens Institute of Technology*
Food  For Exercises 41–43, use the graph that shows the annual production of corn from 1991–2000.

41. Estimate the domain and range of the relation.

42. Which year had the lowest production? the highest?

43. Describe any pattern you see.

Health  For Exercises 44–48, use the following information.
A person’s muscle weight is about 2 pounds of muscle for each 5 pounds of body weight.

44. Make a table to show the relation between body and muscle weight for people weighing 100, 105, 110, 115, 120, 125, and 130 pounds.

45. What are the domain and range?

46. Graph the relation.

47. What are the domain and range of the inverse?

48. Graph the inverse relation.

Critical Thinking  Find a counterexample to disprove the following.

The domain of relation F contains the same elements as the range of relation G. The range of relation F contains the same elements as the domain of relation G. Therefore, relation G must be the inverse of relation F.

Writing in Math  Answer the question that was posed at the beginning of the lesson.

How can relations be used to represent baseball statistics?
Include the following in your answer:
• a graph of the relation of the number of Ken Griffey, Jr.’s, home runs and his strikeouts, and
• an explanation of any relationship between the number of home runs hit and the number of strikeouts.

For Exercises 51 and 52, use the graph at the right.

51. State the domain and range of the relation.
A D = {0, 2, 4}; R = {−4, −2, 0, 2, 4}
B D = {−4, −2, 0, 2, 4}; R = {0, 2, 4}
C D = {0, 2, 4}; R = {−4, −2, 0}
D D = {−4, −2, 0, 2, 4}; R = {−4, −2, 0, 2, 4}

52. Short Response  Graph the inverse of the relation.

For Exercises 53–56, use a graphing calculator.
a. Graph each relation.
b. State the WINDOW settings that you used.
c. Write the coordinates of the inverse. Then graph the inverse.
d. Name the quadrant in which each point of the relation and its inverse lies.

53. {(0, 10), (2, −8), (6, 6), (9, −4)}
54. {(-1, 18), (-2, 23), (-3, 28), (-4, 33)}
55. {(35, 12), (48, 25), (60, 52)}
56. {(-92, -77), (-93, 200), (19, -50)}
Mixed Review

Identify each transformation as a reflection, translation, dilation, or rotation. (Lesson 4-2)

Write the ordered pair for each point shown at the right. Name the quadrant in which the point is located. (Lesson 4-1)

60. A
61. K
62. L
63. W
64. B
65. P
66. R
67. C
68. HOURLY PAY Dominique earns $9.75 per hour. Her employer is increasing her hourly rate to $10.15 per hour. What is the percent of increase in her salary? (Lesson 3-7)

Simplify each expression. (Lesson 2-4)

69. \(72 \div 9\)
70. \(105 \div 15\)
71. \(3 \div \frac{1}{3}\)
72. \(16 \div \frac{1}{4}\)
73. \(\frac{54n + 78}{6}\)
74. \(\frac{98x - 35y}{7}\)

Getting Ready for the Next Lesson

PREREQUISITE SKILL Find the solution set for each equation if the replacement set is \{3, 4, 5, 6, 7, 8\}. (To review solution sets, see Lesson 1-3.)

75. \(a + 15 = 20\)
76. \(r - 6 = 2\)
77. \(9 = 5n - 6\)
78. \(3 + 8w = 35\)
79. \(\frac{8}{3} + 15 = 17\)
80. \(\frac{m}{5} + \frac{3}{5} = 2\)

Practice Quiz 1

Plot each point on a coordinate plane. (Lesson 4-1)

1. \(Q(2, 3)\)
2. \(R(-4, -4)\)
3. \(S(5, -1)\)
4. \(T(-1, 3)\)

Find the coordinates of the vertices of each figure after the given transformation is performed. Then graph the preimage and its image. (Lesson 4-2)

5. triangle \(ABC\) with \(A(4, 8), B(7, 5),\) and \(C(2, -1)\) reflected over the x-axis
6. quadrilateral \(WXYZ\) with \(W(1, 0), X(2, 3), Y(4, 1),\) and \(Z(3, -3)\) translated 5 units to the left and 4 units down

State the domain, range, and inverse of each relation. (Lesson 4-3)

7. \{(1, 3), (4, 6), (2, 3), (1, 5)\}
8. \{(-2, 6), (0, 3), (4, 2), (8, -5)\}
9. \{(11, 5), (15, 3), (-8, 22), (11, 31)\}
10. \{(-5, 8), (-1, 0), (-1, 4), (2, 7), (6, 3)\}
Solve Equations

The equation \( p = 0.69d \) is an example of an equation in two variables. A solution of an equation in two variables is an ordered pair that results in a true statement when substituted into the equation.

Since the solutions of an equation in two variables are ordered pairs, the equation describes a relation. So, in an equation involving \( x \) and \( y \), the set of \( x \) values is the domain, and the corresponding set of \( y \) values is the range.

### Example 1 Solve Using a Replacement Set

Find the solution set for \( y = 2x + 3 \), given the replacement set \( \{(-2, -1), (-1, 3), (0, 4), (3, 9)\} \).

Make a table. Substitute each ordered pair into the equation.

The ordered pairs \((-2, -1)\) and \((3, 9)\) result in true statements.

The solution set is \( \{(-2, -1), (3, 9)\} \).

### Example 2 Solve Using a Given Domain

Solve \( b = a + 5 \) if the domain is \( \{-3, -1, 0, 2, 4\} \).

Make a table. The values of \( a \) come from the domain. Substitute each value of \( a \) into the equation to determine the values of \( b \) in the range.

The solution set is \( \{(-3, 2), (-1, 4), (0, 5), (2, 7), (4, 9)\} \).
**GRAPH SOLUTION SETS** You can graph the ordered pairs in the solution set for an equation in two variables. The domain contains values represented by the independent variable. The range contains the corresponding value represented by the dependent variable.

**Example 3** Solve and Graph the Solution Set

Solve $4x + 2y = 10$ if the domain is $\{-1, 0, 2, 4\}$. Graph the solution set.

First solve the equation for $y$ in terms of $x$. This makes creating a table of values easier.

\[
4x + 2y = 10 \quad \text{Original equation}
\]

\[
4x + 2y - 4x = 10 - 4x \quad \text{Subtract } 4x \text{ from each side.}
\]

\[
2y = 10 - 4x \quad \text{Simplify.}
\]

\[
\frac{2y}{2} = \frac{10 - 4x}{2} \quad \text{Divide each side by } 2.
\]

\[
y = 5 - 2x \quad \text{Simplify.}
\]

Substitute each value of $x$ from the domain to determine the corresponding values of $y$ in the range.

<table>
<thead>
<tr>
<th>$x$</th>
<th>$5 - 2x$</th>
<th>$y$</th>
<th>$(x, y)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-1$</td>
<td>$5 - 2(-1)$</td>
<td>$7$</td>
<td>$(-1, 7)$</td>
</tr>
<tr>
<td>$0$</td>
<td>$5 - 2(0)$</td>
<td>$5$</td>
<td>$(0, 5)$</td>
</tr>
<tr>
<td>$2$</td>
<td>$5 - 2(2)$</td>
<td>$1$</td>
<td>$(2, 1)$</td>
</tr>
<tr>
<td>$4$</td>
<td>$5 - 2(4)$</td>
<td>$-3$</td>
<td>$(4, -3)$</td>
</tr>
</tbody>
</table>

Graph the solution set $\{(-1, 7), (0, 5), (2, 1), (4, -3)\}$.

When you solve an equation for a given variable, that variable becomes the dependent variable. That is, its value depends upon the domain values chosen for the other variable.

**Example 4** Solve for a Dependent Variable

Refer to the application at the beginning of the lesson. Eric has made a list of the expenses he plans to incur while in England. Use the conversion rate to find the equivalent U.S. dollars for these amounts given in pounds (£) and graph the ordered pairs.

**Explore**

In the equation $p = 0.69d$, $d$ represents U.S. dollars and $p$ represents British pounds. However, we are given values in pounds and want to find values in dollars. Solve the equation for $d$ since the values of $d$ depend on the given values of $p$.

\[
p = 0.69d \quad \text{Original equation}
\]

\[
\frac{p}{0.69} = \frac{0.69d}{0.69} \quad \text{Divide each side by } 0.69.
\]

\[
1.45p = d \quad \text{Simplify and round to the nearest hundredth.}
\]

(continued on the next page)
Plan

The values of \( p, \{40, 30, 15, 6\}, \) are the domain. Use the equation \( d = 1.45p \) to find the values for the range.

Solve

Make a table of values. Substitute each value of \( p \) from the domain to determine the corresponding values of \( d \). Round to the nearest dollar.

<table>
<thead>
<tr>
<th>( p )</th>
<th>( 1.45p )</th>
<th>( d )</th>
<th>( (p, d) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>1.45(40)</td>
<td>58.00</td>
<td>(40, 58)</td>
</tr>
<tr>
<td>30</td>
<td>1.45(30)</td>
<td>43.50</td>
<td>(30, 44)</td>
</tr>
<tr>
<td>15</td>
<td>1.45(15)</td>
<td>21.75</td>
<td>(15, 22)</td>
</tr>
<tr>
<td>6</td>
<td>1.45(6)</td>
<td>8.70</td>
<td>(6, 9)</td>
</tr>
</tbody>
</table>

Examine

Look at the values in the range. The cost in dollars is higher than the cost in pounds. Do the results make sense?

**Check for Understanding**

**Concept Check**

1. **Describe** how to find the domain of an equation if you are given the range.

2. **OPEN ENDED** Give an example of an equation in two variables and state two solutions for your equation.

3. **FIND THE ERROR** Malena says that \((5, 1)\) is a solution of \( y = 2x + 3 \). Bryan says it is not a solution.

Málen

\[
\begin{align*}
  y &= 2x + 3 \\
  5 &= 2(1) + 3 \\
  5 &= 5
\end{align*}
\]

Bryan

\[
\begin{align*}
  y &= 2x + 3 \\
  1 &= 2(5) + 3 \\
  1 &= 13
\end{align*}
\]

Who is correct? Explain your reasoning.

**Guided Practice**

Find the solution set for each equation, given the replacement set.

4. \( y = 3x + 4; \{(-1, 1), (2, 10), (3, 12), (7, 1)\} \)

5. \( 2x - 5y = 1; \{(-7, -3), (7, 3), (2, 1), (-2, -1)\} \)

Solve each equation if the domain is \( \{-3, -1, 0, 2\} \).

6. \( y = 2x - 1 \)

7. \( y = 4 - x \)

8. \( 2y + 2x = 12 \)

9. \( 3x + 2y = 13 \)

Solve each equation for the given domain. Graph the solution set.

10. \( y = 3x \) for \( x = \{-3, -2, -1, 0, 1, 2, 3\} \)

11. \( 2y = x + 2 \) for \( x = \{-4, -2, 0, 2, 4\} \)
Application  

JEWELRY  For Exercises 12 and 13, use the following information.
Since pure gold is very soft, other metals are often added to it to make an alloy that is stronger and more durable. The relative amount of gold in a piece of jewelry is measured in karats. The formula for the relationship is \( g = \frac{25k}{6} \), where \( k \) is the number of karats and \( g \) is the percent of gold in the jewelry.

12. Find the percent of gold if the domain is \{10, 14, 18, 24\}. Make a table of values and graph the function.

13. How many karats are in a ring that is 50% gold?

Practice and Apply

Find the solution set for each equation, given the replacement set.

14. \( y = 4x + 1 \) \{\{(2, -1), (1, 5), (9, 2), (0, 1)\}\}
15. \( y = 8 - 3x \) \{\{(4, -4), (8, 0), (2, 2), (3, 3)\}\}
16. \( x - 3y = -7 \) \{\{(-1, 2), (2, -1), (2, 4), (2, 3)\}\}
17. \( 2x + 2y = 6 \) \{\{(3, 0), (2, 1), (-2, -1), (4, -1)\}\}
18. \( 3x - 8y = -4 \) \{\{(0, 0.5), (4, 1), (2, 0.75), (2, 4)\}\}
19. \( 2y + 4x = 8 \) \{\{(0, 2), (-3, 0.5), (0.25, 3.5), (1, 2)\}\}

Solve each equation if the domain is \{-2, -1, 1, 3, 4\}.

20. \( y = 4 - 5x \)
21. \( y = 2x + 3 \)
22. \( x = y + 4 \)
23. \( x = 7 - y \)
24. \( 6x - 3y = 18 \)
25. \( 6x - y = -3 \)
26. \( 8x + 4y = 12 \)
27. \( 2x - 2y = 0 \)
28. \( 5x - 10y = 20 \)
29. \( 3x + 2y = 14 \)
30. \( x + \frac{1}{2}y = 8 \)
31. \( 2x - \frac{1}{3}y = 4 \)

Solve each equation for the given domain. Graph the solution set.

32. \( y = 2x + 3 \) for \( x = \{-3, -2, -1, 1, 2, 3\}\)
33. \( y = 3x - 1 \) for \( x = \{-5, -2, 1, 3, 4\}\)
34. \( 3x - 2y = 5 \) for \( x = \{-3, -1, 2, 4, 5\}\)
35. \( 5x + 4y = 8 \) for \( x = \{-4, -1, 0, 2, 4, 6\}\)
36. \( \frac{1}{2}x + y = 2 \) for \( x = \{-4, -1, 1, 4, 7, 8\}\)
37. \( y = \frac{1}{4}x - 3 \) for \( x = \{-4, -2, 0, 2, 4, 6\}\)
38. The domain for \( 3x + y = 8 \) is \{-1, 2, 5, 8\}. Find the range.
39. The range for \( 2y - x = 6 \) is \{-4, -3, 1, 6, 7\}. Find the domain.

TRAVEL  For Exercises 40 and 41, use the following information.

Heinrich and his brother live in Germany. They are taking a trip to the United States and have been checking the average temperatures in different U.S. cities for the month they will be traveling. They are unfamiliar with the Fahrenheit scale, so they would like to convert the temperatures to Celsius. The equation \( F = 1.8C + 32 \) relates the temperature in degrees Celsius \( C \) to degrees Fahrenheit \( F \).

40. Solve the equation for \( C \).
41. Find the temperatures in degrees Celsius for each city.

<table>
<thead>
<tr>
<th>City</th>
<th>Temperature (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York</td>
<td>34</td>
</tr>
<tr>
<td>Chicago</td>
<td>23</td>
</tr>
<tr>
<td>San Francisco</td>
<td>55</td>
</tr>
<tr>
<td>Miami</td>
<td>72</td>
</tr>
<tr>
<td>Washington, D.C.</td>
<td>40</td>
</tr>
</tbody>
</table>

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**GEOMETRY** For Exercises 42–44, use the following information. The equation for the perimeter of a rectangle is \( P = 2\ell + 2w \). Suppose the perimeter of rectangle \( ABCD \) is 24 centimeters.

42. Solve the equation for \( \ell \).
43. State the independent and dependent variables.
44. Choose five values for \( w \) and find the corresponding values of \( \ell \).

**ANTHROPOLOGY** When the remains of ancient people are discovered, usually only a few bones are found. Anthropologists can determine a person’s height by using a formula that relates the length of the tibia \( T \) (shin bone) to the person’s height \( H \), both measured in centimeters. The formula for males is \( H = 81.7 + 2.4T \) and for females is \( H = 72.6 + 2.5T \). Copy and complete the tables below. Then graph each set of ordered pairs.

<table>
<thead>
<tr>
<th>Length of Tibia (cm)</th>
<th>Height (cm)</th>
<th>((T, H))</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>37.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**RESEARCH** Choose a country that you would like to visit. Use the Internet or other reference to find the cost of various services such as hotels, meals, and transportation. Use the currency exchange rate to determine how much money in U.S. dollars you will need on your trip.

**CRITICAL THINKING** Find the domain values of each relation if the range is \( \{0, 16, 36\} \).

a. \( y = x^2 \)  

b. \( y = |4x| - 16 \)  

c. \( y = |4x - 16| \)

**CRITICAL THINKING** Select five values for the domain and find the range of \( y = x + 4 \). Then look at the range and domain of the inverse relation. Make a conjecture about the equation that represents the inverse relation.

**WRITING IN MATH** Answer the question that was posed at the beginning of the lesson.

Why are equations of relations important in traveling?

Include the following in your answer:

- an example of how you would keep track of how much you were spending in pounds and the equivalent amount in dollars, and
- an explanation of your spending power if the currency exchange rate is 0.90 pound compared to one U.S. dollar or 1.04 pounds compared to one dollar.

50. If \( 3x - y = 18 \) and \( y = 3 \), then \( x = \)

- A) 4  
- B) 5  
- C) 6  
- D) 7

51. If the perimeter of a rectangle is 14 units and the area is 12 square units, what are the dimensions of the rectangle?

- A) 2 \times 6  
- B) 3 \times 3  
- C) 3 \times 4  
- D) 1 \times 12
**TABLE FEATURE**  You can enter selected x values in the TABLE feature of a graphing calculator, and it will calculate the corresponding y values for a given equation. To do this, enter an equation into the Y= list. Go to TBLSET and highlight Ask under the Independent variable. Now you can use the TABLE function to enter any domain value and the corresponding range value will appear in the second column.

Use a graphing calculator to find the solution set for the given equation and domain.

52. \( y = 3x - 4; x = \{-11, 15, 23, 44\} \)
53. \( y = -6.5x + 42; x = \{-8, -5, 0, 3, 12\} \)
54. \( y = 3x + 12 \) for \( x = \{0.4, 0.6, 1.8, 2.2, 3.1\} \)
55. \( y = 1.4x - 0.76 \) for \( x = \{-2.5, -1.75, 0, 1.25, 3.33\} \)

**Maintain Your Skills**

**Mixed Review**  Express the relation shown in each table, mapping, or graph as a set of ordered pairs. Then write the inverse of the relation.  (Lesson 4-3)

56.  
<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>-2</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>-4</td>
<td>2</td>
</tr>
</tbody>
</table>

57.  
<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>-4</td>
</tr>
<tr>
<td>6</td>
<td>-1</td>
</tr>
<tr>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

58.  

Find the coordinates of the vertices of each figure after the given transformation is performed. Then graph the preimage and its image.  (Lesson 4-2)
59.  triangle \( XYZ \) with \( X(-6, 4), Y(-5, 0), \) and \( Z(3, 3) \) reflected over the \( y \)-axis
60.  quadrilateral \( QRST \) with \( Q(2, 2), R(3, -3), S(-1, -4) \) and \( T(-4, -3) \) rotated 90° counterclockwise about the origin

Use cross products to determine whether each pair of ratios forms a proportion.  Write yes or no.  (Lesson 3-6)

61.  \[ \frac{6}{15}, \frac{18}{45} \]
62.  \[ \frac{11}{12}, \frac{33}{34} \]
63.  \[ \frac{8}{22}, \frac{20}{55} \]
64.  \[ \frac{6}{8}, \frac{3}{4} \]
65.  \[ \frac{3}{5}, \frac{9}{25} \]
66.  \[ \frac{26}{35}, \frac{12}{15} \]

Identify the hypothesis and conclusion of each statement.  (Lesson 1-7)
67.  If it is hot, then we will go swimming.
68.  If you do your chores, then you get an allowance.
69.  If \( 3n - 7 = 17 \), then \( n = 8 \).
70.  If \( a > b \) and \( b > c \), then \( a > c \).

**Getting Ready for the Next Lesson**  

**PREREQUISITE SKILL**  Solve each equation.  (To review solving equations, see Lesson 3-4.)

71.  \( a + 15 = 20 \)
72.  \( r - 9 = 12 \)
73.  \( -4 = 5n + 6 \)
74.  \( 3 - 8w = 35 \)
75.  \( \frac{8}{4} + 2 = 5 \)
76.  \( \frac{m}{5} + \frac{3}{5} = 2 \)
Standard Form of a Linear Equation

The standard form of a linear equation is

\[ Ax + By = C, \]

where \( A \neq 0 \), \( A \) and \( B \) are not both zero, and \( A, B, \) and \( C \) are integers whose greatest common factor is 1.

**Identify Linear Equations**

A linear equation can be written in the form \( Ax + By = C \). This is called the standard form of a linear equation.

**Key Concept**

**Standard Form of a Linear Equation**

The standard form of a linear equation is

\[ Ax + By = C, \]

where \( A \neq 0 \), \( A \) and \( B \) are not both zero, and \( A, B, \) and \( C \) are integers whose greatest common factor is 1.

**Example 1** Identify Linear Equations

Determine whether each equation is a linear equation. If so, write the equation in standard form.

a. \( y = 5 - 2x \)

First rewrite the equation so that both variables are on the same side of the equation.

\[
\begin{align*}
    y & = 5 - 2x \\
    y + 2x & = 5 - 2x + 2x \\
    2x + y & = 5
\end{align*}
\]

Add 2x to each side. Simplify.

The equation is now in standard form where \( A = 2, B = 1, \) and \( C = 5 \). This is a linear equation.

b. \( 2xy - 5y = 6 \)

Since the term \( 2xy \) has two variables, the equation cannot be written in the form \( Ax + By = C \). Therefore, this is not a linear equation.
c. \(3x + 9y = 15\)

Since the GCF of 3, 9, and 15 is not 1, the equation is not written in standard form. Divide each side by the GCF.

\[
3x + 9y = 15 \quad \text{Original equation}
\]

\[
3(x + 3y) = 15 \quad \text{Factor the GCF.}
\]

\[
\frac{3(x + 3y)}{3} = \frac{15}{3} \quad \text{Divide each side by 3.}
\]

\[
x + 3y = 5 \quad \text{Simplify.}
\]

The equation is now in standard form where \(A = 1, B = 3,\) and \(C = 5.\)

\[d. \quad \frac{1}{3}y = -1\]

To write the equation with integer coefficients, multiply each term by 3.

\[
\frac{1}{3}y = -1 \quad \text{Original equation}
\]

\[
3\left(\frac{1}{3}y\right) = 3(-1) \quad \text{Multiply each side of the equation by 3.}
\]

\[
y = -3 \quad \text{Simplify.}
\]

The equation \(y = -3\) can be written as \(0x + y = -3.\) Therefore, it is a linear equation in standard form where \(A = 0, B = 1,\) and \(C = -3.\)

**GRAPH LINEAR EQUATIONS**

The graph of a linear equation is a line. The line represents all the solutions of the linear equation. Also, every ordered pair on this line satisfies the equation.

**Example 2** *Graph by Making a Table*

Graph \(x + 2y = 6.\)

In order to find values for \(y\) more easily, solve the equation for \(y.\)

\[
x + 2y = 6 \quad \text{Original equation}
\]

\[
x + 2y - x = 6 - x \quad \text{Subtract \(x\) from each side.}
\]

\[
2y = 6 - x \quad \text{Simplify.}
\]

\[
\frac{2y}{2} = \frac{6 - x}{2} \quad \text{Divide each side by 2.}
\]

\[
y = 3 - \frac{1}{2}x \quad \text{Simplify.}
\]

Select five values for the domain and make a table. Then graph the ordered pairs.

<table>
<thead>
<tr>
<th>(x)</th>
<th>(3 - \frac{1}{2}x)</th>
<th>(y)</th>
<th>((x, y))</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2</td>
<td>3 - (\frac{1}{2}(-2))</td>
<td>4</td>
<td>(-2, 4)</td>
</tr>
<tr>
<td>0</td>
<td>3 - (\frac{1}{2}(0))</td>
<td>3</td>
<td>(0, 3)</td>
</tr>
<tr>
<td>2</td>
<td>3 - (\frac{1}{2}(2))</td>
<td>2</td>
<td>(2, 2)</td>
</tr>
<tr>
<td>4</td>
<td>3 - (\frac{1}{2}(4))</td>
<td>1</td>
<td>(4, 1)</td>
</tr>
<tr>
<td>6</td>
<td>3 - (\frac{1}{2}(6))</td>
<td>0</td>
<td>(6, 0)</td>
</tr>
</tbody>
</table>

*(continued on the next page)*
When you graph the ordered pairs, a pattern begins to form. The domain of \( y = 3 - \frac{1}{2}x \) is the set of all real numbers, so there are an infinite number of solutions of the equation. Draw a line through the points. This line represents all of the solutions of \( y = 3 - \frac{1}{2}x \).

**Example 3**  
**Use the Graph of a Linear Equation**

**PHYSICAL FITNESS** Carlos swims every day. He burns approximately 10.6 Calories per minute when swimming laps.

a. Graph the equation \( C = 10.6t \), where \( C \) represents the number of Calories burned and \( t \) represents the time in minutes spent swimming.

Select five values for \( t \) and make a table. Graph the ordered pairs and connect them to draw a line.

<table>
<thead>
<tr>
<th>( t )</th>
<th>10.6( t )</th>
<th>( C )</th>
<th>((t, C))</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10.6(10)</td>
<td>106</td>
<td>(10, 106)</td>
</tr>
<tr>
<td>15</td>
<td>10.6(15)</td>
<td>159</td>
<td>(15, 159)</td>
</tr>
<tr>
<td>20</td>
<td>10.6(20)</td>
<td>212</td>
<td>(20, 212)</td>
</tr>
<tr>
<td>30</td>
<td>10.6(30)</td>
<td>318</td>
<td>(30, 318)</td>
</tr>
</tbody>
</table>

b. Suppose Carlos wanted to burn 350 Calories. Approximately how long should he swim?

Since any point on the line is a solution of the equation, use the graph to estimate the value of the \( x \)-coordinate in the ordered pair that contains 350 as the \( y \)-coordinate. The ordered pair (33, 350) appears to be on the line so Carlos should swim for 33 minutes to burn 350 Calories.  

Check this solution algebraically by substituting (33, 350) into the original equation.

Since two points determine a line, a simple method of graphing a linear equation is to find the points where the graph crosses the \( x \)-axis and the \( y \)-axis. The \( x \)-coordinate of the point at which it crosses the \( x \)-axis is the \( x \)-intercept, and the \( y \)-coordinate of the point at which the graph crosses the \( y \)-axis is called the \( y \)-intercept.

**Example 4**  
**Graph Using Intercepts**

Determine the \( x \)-intercept and \( y \)-intercept of \( 3x + 2y = 9 \). Then graph the equation.

To find the \( x \)-intercept, let \( y = 0 \).

\[
3x + 2y = 9 \quad \text{Original equation} \\
3x + 2(0) = 9 \quad \text{Replace } y \text{ with } 0. \\
3x = 9 \quad \text{Divide each side by } 3. \\
x = 3
\]

To find the \( y \)-intercept, let \( x = 0 \).

\[
3x + 2y = 9 \quad \text{Original equation} \\
3(0) + 2y = 9 \quad \text{Replace } x \text{ with } 0. \\
2y = 9 \quad \text{Divide each side by } 2. \\
y = 4.5
\]
The x-intercept is 3, so the graph intersects the x-axis at (3, 0). The y-intercept is 4.5, so the graph intersects the y-axis at (0, 4.5). Plot these points. Then draw a line that connects them.

Check for Understanding

Concept Check
1. Explain how the graph of \( y = 2x + 1 \) for the domain \{1, 2, 3, 4\} differs from the graph of \( y = 2x + 1 \) for the domain of all real numbers.

2. OPEN ENDED Give an example of a linear equation in the form \( Ax + By = C \) for each of the following conditions.
   a. \( A = 0 \)
   b. \( B = 0 \)
   c. \( C = 0 \)

3. Explain how to graph an equation using the x- and y-intercepts.

Guided Practice
Determine whether each equation is a linear equation. If so, write the equation in standard form.

4. \( x + y^2 = 25 \)
5. \( 3y + 2 = 0 \)
6. \( \frac{3}{5}x - \frac{2}{5}y = 5 \)
7. \( x + \frac{1}{y} = 7 \)

Graph each equation.
8. \( x = 3 \)
9. \( x - y = 0 \)
10. \( y = 2x + 8 \)
11. \( y = -3 - x \)
12. \( x + 4y = 10 \)
13. \( 4x + 3y = 12 \)

Application
TAXI FARE For Exercises 14 and 15, use the following information.
A taxi company charges a fare of $2.25 plus $0.75 per mile traveled. The cost of the fare \( c \) can be described by the equation \( c = 0.75m + 2.25 \), where \( m \) is the number of miles traveled.

14. Graph the equation.
15. If you need to travel 18 miles, how much will the taxi fare cost?

Practice and Apply
Determine whether each equation is a linear equation. If so, write the equation in standard form.

16. \( 3x = 5y \)
17. \( 6 - y = 2x \)
18. \( 6xy + 3x = 4 \)
19. \( y + 5 = 0 \)
20. \( 7y = 2x + 5x \)
21. \( y = 4x^2 - 1 \)
22. \( \frac{3}{x} + \frac{4}{y} = 2 \)
23. \( \frac{x}{2} = 10 + \frac{2y}{3} \)
24. \( 7n - 8m = 4 - 2m \)
25. \( 3a + b - 2 = b \)

Graph each equation.

26. \( y = -1 \)
27. \( y = 2x \)
28. \( y = 5 - x \)
29. \( y = 2x - 8 \)
30. \( y = 4 - 3x \)
31. \( y = x - 6 \)
32. \( x = 3y \)
33. \( x = 4y - 6 \)
34. \( x - y = -3 \)
35. \( x + 3y = 9 \)
36. \( 4x + 6y = 8 \)
37. \( 3x - 2y = 15 \)

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Graph each equation.
38. $1.5x + y = 4$  
39. $2.5x + 5y = 75$  
40. $\frac{1}{2}x + y = 4$  
41. $x - \frac{2}{3}y = 1$  
42. $\frac{4x}{3} = \frac{3y}{4} + 1$  
43. $y + \frac{1}{3} = \frac{1}{4}x - 3$

44. Find the $x$- and $y$-intercept of the graph of $4x - 7y = 14$.
45. Write an equation in standard form of the line with an $x$-intercept of 3 and a $y$-intercept of 5.

**GEOMETRY** For Exercises 46–48, refer to the figure.
The perimeter $P$ of a rectangle is given by $2\ell + 2w = P$, where $\ell$ is the length of the rectangle and $w$ is the width.

46. If the perimeter of the rectangle is 30 inches, write an equation for the perimeter in standard form.
47. What are the $x$- and $y$-intercepts of the graph of the equation?
48. Graph the equation.

**METEOROLOGY** For Exercises 49–51, use the following information.
As a thunderstorm approaches, you see lightning as it occurs, but you hear the accompanying sound of thunder a short time afterward. The distance $d$ in miles that sound travels in $t$ seconds is given by the equation $d = 0.21t$.

49. Make a table of values.
50. Graph the equation.
51. Estimate how long it will take to hear the thunder from a storm 3 miles away.

**BIOLOGY** For Exercises 52 and 53, use the following information.
The amount of blood in the body can be predicted by the equation $y = 0.07w$, where $y$ is the number of pints of blood and $w$ is the weight of a person in pounds.

52. Graph the equation.
53. Predict the weight of a person whose body holds 12 pints of blood.

**OCEANOGRAPHY** For Exercises 54–56, use the information at left and below.
Under water, pressure increases 4.3 pounds per square inch (psi) for every 10 feet you descend. This can be expressed by the equation $p = 0.43d + 14.7$, where $p$ is the pressure in pounds per square inch and $d$ is the depth in feet.

54. Graph the equation.
55. Divers cannot work at depths below about 400 feet. What is the pressure at this depth?
56. How many times as great is the pressure at 400 feet as the pressure at sea level?

57. **CRITICAL THINKING** Explain how you can determine whether a point at $(x, y)$ is above, below, or on the line given by $2x - y = 8$ without graphing it. Give an example of each.

58. **WRITING IN MATH** Answer the question that was posed at the beginning of the lesson.

How can linear equations be used in nutrition?
Include the following in your answer:
• an explanation of how you could use the Nutrition Information labels on packages to limit your fat intake, and
• an equation you could use to find how many grams of protein you should have each day if you wanted 10% of your diet to consist of protein. (*Hint:* Protein contains 4 Calories per gram.)
59. Which point lies on the line given by \( y = 3x - 5? \)
   - A) \((1, -2)\)
   - B) \((0, 5)\)
   - C) \((1, 2)\)
   - D) \((4, 3)\)

60. In the graph at the right, \((0, 1)\) and \((4, 3)\) lie on the line. Which ordered pair also lies on the line?
   - A) \((1, 1)\)
   - B) \((2, 2)\)
   - C) \((3, 3)\)
   - D) \((4, 4)\)

### Maintain Your Skills

**Mixed Review**

Solve each equation if the domain is \((-3, -1, 2, 5, 8)\).  
(Lesson 4-4)

61. \( y = x - 5 \)
62. \( y = 2x + 1 \)
63. \( 3x + y = 12 \)
64. \( 2x - y = -3 \)
65. \( 3x - \frac{1}{2}y = 6 \)
66. \(-2x + \frac{1}{3}y = 4 \)

Express each relation as a table, a graph, and a mapping. Then determine the domain and range.  
(Lesson 4-3)

67. \{ (3, 5), (-4, -1), (-3, 2), (3, 1) \}
68. \{ (4, 0), (2, -3), (-1, -3), (4, 4) \}
69. \{ (1, 4), (3, 0), (-1, -1), (3, 5) \}
70. \{ (4, 5), (2, 5), (4, -1), (3, 2) \}

Solve each equation. Then check your solution.  
(Lesson 3-5)

71. \( 2(x - 2) = 3x - (4x - 5) \)
72. \( 3a + 8 = 2a - 4 \)
73. \( 3n - 12 = 5n - 20 \)
74. \( 6(x + 3) = 3x \)

**ANIMALS**  For Exercises 75–78, use the table below that shows the average life spans of 20 different animals.  
(Lesson 2-5)

<table>
<thead>
<tr>
<th>Animal</th>
<th>Life Span (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baboon</td>
<td>20</td>
</tr>
<tr>
<td>Camel</td>
<td>12</td>
</tr>
<tr>
<td>Cow</td>
<td>15</td>
</tr>
<tr>
<td>Elephant</td>
<td>40</td>
</tr>
<tr>
<td>Fox</td>
<td>7</td>
</tr>
<tr>
<td>Gorilla</td>
<td>20</td>
</tr>
<tr>
<td>Hippopotamus</td>
<td>25</td>
</tr>
<tr>
<td>Kangaroo</td>
<td>7</td>
</tr>
<tr>
<td>Lion</td>
<td>15</td>
</tr>
<tr>
<td>Monkey</td>
<td>15</td>
</tr>
<tr>
<td>Mouse</td>
<td>3</td>
</tr>
<tr>
<td>Opossum</td>
<td>1</td>
</tr>
<tr>
<td>Pig</td>
<td>10</td>
</tr>
<tr>
<td>Rabbit</td>
<td>5</td>
</tr>
<tr>
<td>Sea Lion</td>
<td>12</td>
</tr>
<tr>
<td>Sheep</td>
<td>12</td>
</tr>
</tbody>
</table>

75. Make a line plot of the average life spans of the animals in the table.
76. How many animals live between 7 and 16 years?
77. Which number occurred most frequently?
78. How many animals live at least 20 years?

### PREREQUISITE SKILL

Evaluate each expression.  
(To review evaluating expressions, see Lesson 1-2.)

79. \( 19 + 5 \cdot 4 \)
80. \( (25 - 4) \div (2^2 - 1^3) \)
81. \( 12 \div 4 + 15 \cdot 3 \)
82. \( 12(19 - 15) - 3 \cdot 8 \)
83. \( 6(4^3 + 2^2) \)
84. \( 7[4^3 - 2(4 + 3)] \div 7 + 2 \)

**Getting Ready for the Next Lesson**

Lesson 4-5  Graphing Linear Equations
Graphing Linear Equations

The power of a graphing calculator is the ability to graph different types of equations accurately and quickly. Often linear equations are graphed in the standard viewing window. The **standard viewing window** is $[-10, 10]$ by $[-10, 10]$ with a scale of 1 on both axes. To quickly choose the standard viewing window on a TI-83 Plus, press **ZOOM** 6.

**Example 1**
Graph $2x - y = 3$ on a TI-83 Plus graphing calculator.

**Step 1** **Enter the equation in the Y= list.**

- The Y= list shows the equation or equations that you will graph.
- Equations must be entered with the $y$ isolated on one side of the equation. Solve the equation for $y$, then enter it into the calculator.

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

  **KEYSTROKES:** $Y= 2 \ X,T,\theta,n \ - 3$

**Step 2** **Graph the equation in the standard viewing window.**

Graph the selected equations.

  **KEYSTROKES:** **ZOOM** 6

Notice that the graph of $2x - y = 3$ above is a complete graph because all of these points are visible.

Sometimes a complete graph is not displayed using the standard viewing window. A **complete graph** includes all of the important characteristics of the graph on the screen. These include the origin, and the $x$- and $y$-intercepts.

When a complete graph is not displayed using the standard viewing window, you will need to change the viewing window to accommodate these important features. You can use what you have learned about intercepts to help you choose an appropriate viewing window.

[www.algebra1.com/other_calculator_keystrokes](http://www.algebra1.com/other_calculator_keystrokes)
Investigation

Example 2
Graph \( y = 3x - 15 \) on a graphing calculator.

Step 1 Enter the equation in the Y= list and graph in the standard viewing window.

Clear the previous equation from the Y= list. Then enter the new equation and graph.

KEYSTROKES: \( \text{Y= CLEAR 3 X,T,0,n} -15 \text{ ZOOM 6} \)

Step 2 Modify the viewing window and graph again.

The origin and the \( x \)-intercept are displayed in the standard viewing window. But notice that the \( y \)-intercept is outside of the viewing window. Find the \( y \)-intercept.

\[
y = 3x - 15 \quad \text{Original equation}
\]

\[
y = 3(0) - 15 \quad \text{Replace} \ x \ \text{with} \ 0.
\]

\[
y = -15 \quad \text{Simplify.}
\]

Since the \( y \)-intercept is \(-15\), choose a viewing window that includes a number less than \(-15\). The window \([-10, 10]\) by \([-20, 5]\) with a scale of 1 on each axis is a good choice.

KEYSTROKES: \( \text{WINDOW -10 ENTER 10 ENTER 1 ENTER} \)

\[
\quad -20 \text{ ENTER 5 ENTER 1 GRAPH}
\]

Exercises
Use a graphing calculator to graph each equation in the standard viewing window. Sketch the result.

1. \( y = x + 2 \)
2. \( y = 4x + 5 \)
3. \( y = 6 - 5x \)
4. \( 2x + y = 6 \)
5. \( x + y = -2 \)
6. \( x - 4y = 8 \)

Graph each linear equation in the standard viewing window. Determine whether the graph is complete. If the graph is not complete, choose a viewing window that will show a complete graph and graph the equation again.

7. \( y = 5x + 9 \)
8. \( y = 10x - 6 \)
9. \( y = 3x - 18 \)
10. \( 3x - y = 12 \)
11. \( 4x + 2y = 21 \)
12. \( 3x + 5y = -45 \)

For Exercises 13–15, consider the linear equation \( y = 2x + b \).

13. Choose several different positive and negative values for \( b \). Graph each equation in the standard viewing window.
14. For which values of \( b \) is the complete graph in the standard viewing window?
15. How is the value of \( b \) related to the \( y \)-intercept of the graph of \( y = 2x + b \)?
### Vocabulary
- function
- vertical line test
- function notation

### Functions

#### What You’ll Learn
- Determine whether a relation is a function.
- Find function values.

#### How are functions used in meteorology?

The table shows barometric pressures and temperatures recorded by the National Climatic Data Center over a three-day period.

<table>
<thead>
<tr>
<th>Pressure (millibars)</th>
<th>1013</th>
<th>1006</th>
<th>997</th>
<th>995</th>
<th>995</th>
<th>1000</th>
<th>1006</th>
<th>1011</th>
<th>1016</th>
<th>1019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>3</td>
<td>4</td>
<td>10</td>
<td>13</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>

Notice that when the pressure is 995 and 1006 millibars, there is more than one value for the temperature.

#### IDENTIFY FUNCTIONS

Recall that relations in which each element of the domain is paired with exactly one element of the range are called **functions**.

#### Example 1 Identify Functions

Determine whether each relation is a function. Explain.

**a.**

This mapping represents a function since, for each element of the domain, there is only one corresponding element in the range. It does not matter if two elements of the domain are paired with the same element in the range.

**b.**

This table represents a relation that is not a function. The element 2 in the domain is paired with both 5 and 4 in the range. If you are given that \( x = 2 \), you cannot determine the value of \( y \).

**c.** \((-2, 4), (1, 5), (3, 6), (5, 8), (7, 10)\)

Since each element of the domain is paired with exactly one element of the range, this relation is a function. If you are given that \( x = -3 \), you can determine that the value of \( y \) is 6 since 6 is the only value of \( y \) that is paired with \( x = 3 \).
You can use the **vertical line test** to see if a graph represents a function. If no vertical line can be drawn so that it intersects the graph more than once, then the graph is a function. If a vertical line can be drawn so that it intersects the graph at two or more points, the relation is not a function.

One way to perform the vertical line test is to use a pencil.

**Example 2**  Equations as Functions

Determine whether \(2x - y = 6\) is a function.

Graph the equation using the \(x\)- and \(y\)-intercepts.

Since the equation is in the form \(Ax + By = C\), the graph of the equation will be a line. Place your pencil at the left of the graph to represent a vertical line. Slowly move the pencil to the right across the graph.

For each value of \(x\), this vertical line passes through no more than one point on the graph. Thus, the line represents a function.

**FUNCTION VALUES** Equations that are functions can be written in a form called **function notation**. For example, consider \(y = 3x - 8\).

\[
\begin{align*}
\text{equation} & \quad y = 3x - 8 \\
\text{function notation} & \quad f(x) = 3x - 8
\end{align*}
\]

In a function, \(x\) represents the elements of the domain, and \(f(x)\) represents the elements of the range. Suppose you want to find the value in the range that corresponds to the element 5 in the domain. This is written \(f(5)\) and is read “f of 5.” The value \(f(5)\) is found by substituting 5 for \(x\) in the equation.

**Example 3**  Function Values

If \(f(x) = 2x + 5\), find each value.

a. \(f(-2)\)

\[
f(-2) = 2(-2) + 5 = -4 + 5 = 1
\]

Replace \(x\) with -2.  Multiply.  Add.

b. \(f(1) + 4\)

\[
f(1) + 4 = [2(1) + 5] + 4 = 7 + 4 = 11
\]

Replace \(x\) with 1.  Simplify.  Add.
1. Study the following set of ordered pairs that describe a relation between \( x \) and \( y \):
\[
(1, \frac{1}{2}), (1, 2), (4, 3), (2, \frac{2}{3}), (3, 2), (3, 4), (3, 3).
\]
Is \( y \) a function of \( x \)? Is \( x \) a function of \( y \)? Explain your answer.

2. OPEN ENDED Define a function using nonstandard function notation.

3. Find a counterexample to disprove the following statement.

The functions we have studied thus far have been linear functions. However, many functions are not linear. You can find the value of these functions in the same way.

**Example 4** Nonlinear Function Values

If \( h(z) = z^2 + 3z - 4 \), find each value.

a. \( h(-4) \)
\[
h(-4) = (-4)^2 + 3(-4) - 4 \quad \text{Replace } z \text{ with } -4.
\]
\[
= 16 - 12 - 4 \quad \text{Multiply.}
\]
\[
= 0 \quad \text{Simplify.}
\]

b. \( h(5a) \)
\[
h(5a) = (5a)^2 + 3(5a) - 4 \quad \text{Replace } z \text{ with } 5a.
\]
\[
= 25a^2 + 15a - 4 \quad \text{Simplify.}
\]

c. \( 2[h(g)] \)
\[
2[h(g)] = 2[(g)^2 + 3(g) - 4] \quad \text{Evaluate } h(g) \text{ by replacing } z \text{ with } g.
\]
\[
= 2g^2 + 6g - 8 \quad \text{Multiply the value of } h(g) \text{ by } 2.
\]

On some standardized tests, an arbitrary symbol may be used to represent a function.

**Example 5** Nonstandard Function Notation

Multiple-Choice Test Item

If \( << x >> = x^2 - 4x + 2 \), then \( << 3 >> = \)

\(\text{A} -2, \quad \text{B} -1, \quad \text{C} 1, \quad \text{D} 2.\)

Read the Test Item
The symbol \( << x >> \) is just a different notation for \( f(x) \).

Solve the Test Item
Replace \( x \) with 3.
\[
<< x >> = x^2 - 4x + 2 \quad \text{Think: } << x >> = f(x)
\]
\[
<< 3 >> = (3)^2 - 4(3) + 2 \quad \text{Replace } x \text{ with } 3.
\]
\[
= 9 - 12 + 2 \text{ or } -1 \quad \text{The answer is B.}
\]

**Check for Understanding**

**Concept Check**

1. Study the following set of ordered pairs that describe a relation between \( x \) and \( y \):
\[
(1, -1), (-1, 2), (4, -3), (3, 2), (-2, 4), (3, -3).\]
Is \( y \) a function of \( x \)? Is \( x \) a function of \( y \)? Explain your answer.

2. OPEN ENDED Define a function using nonstandard function notation.

3. Find a counterexample to disprove the following statement.

All linear equations are functions.
Determine whether each relation is a function.

4. \((x, y)\) graph

5. \(\begin{array}{c|c}
-3 & 0 \\
2 & 1 \\
2 & 4 \\
6 & 5 \\
\end{array}\)

6. \(\{(24, 1), (21, 4), (3, 22), (24, 5)\}\)

7. \(y = x + 3\)

8. \(x\) and \(y\) values graph

9. \(x\) and \(y\) values graph

If \(f(x) = 4x - 5\) and \(g(x) = x^2 + 1\), find each value.

10. \(f(2)\)

11. \(g(-1)\)

12. \(f(c)\)

13. \(g(t) - 4\)

14. \(f(3a^2)\)

16. If \(x^{**} = 2x - 1\), then \(5^{**} - 2^{**} = \)
   
   \[\text{A} \quad 3. \quad \text{B} \quad 4. \quad \text{C} \quad 5. \quad \text{D} \quad 6.\]

Practice and Apply

Determine whether each relation is a function.

17. \((x, y)\) graph

18. \((x, y)\) graph

19. \(\begin{array}{c|c}
2 & 7 \\
4 & 9 \\
5 & 5 \\
8 & -1 \\
\end{array}\)

20. \(\begin{array}{c|c}
-9 & -5 \\
-4 & 0 \\
3 & 6 \\
7 & 1 \\
6 & -5 \\
3 & 2 \\
\end{array}\)

21. \(x\) and \(y\) values graph

22. \(x\) and \(y\) values graph

23. \(\{(5, -7), (6, -7), (-8, -1), (0, -1)\}\)

24. \(\{(4, 5), (3, -2), (-2, 5), (4, 7)\}\)

25. \(y = -8\)

26. \(x = 15\)

27. \(y = 3x - 2\)

28. \(y = 3x + 2y\)
Determine whether each relation is a function.

29. [Graph]
30. [Graph]
31. [Graph]

If \( f(x) = 3x + 7 \) and \( g(x) = x^2 - 2x \), find each value.

32. \( f(3) \)
33. \( f(-2) \)
34. \( g(5) \)
35. \( g(0) \)
36. \( g(-3) + 1 \)
37. \( f(8) - 5 \)
38. \( g(2c) \)
39. \( f(a^2) \)
40. \( f(k + 2) \)
41. \( f(2m - 5) \)
42. \( 3[g(x) + 4] \)
43. \( 2[f(x^2) - 5] \)

44. **PARKING** The rates for a parking garage are as follows: $2.00 for the first hour; $2.75 for the second hour; $3.50 for the third hour; $4.25 for the fourth hour; and $5.00 for any time over four hours. Choose the graph that best represents the information given and determine whether the graph represents a function. Explain your reasoning.

45. Write the equation in function notation.
46. Find \( f(100) \), \( f(200) \), and \( f(1000) \).
47. Graph the equation.
48. Use the graph of the function to determine the temperature at 4000 feet.

**CLIMATE** For Exercises 45–48, use the following information.

The temperature of the atmosphere decreases about \( 5^\circ F \) for every 1000 feet increase in altitude. Thus, if the temperature at ground level is \( 77^\circ F \), the temperature at a given altitude is found by using the equation \( t = 77 - 0.005h \), where \( h \) is the height in feet.

45. Write the equation in function notation.
46. Find \( f(100) \), \( f(200) \), and \( f(1000) \).
47. Graph the equation.
48. Use the graph of the function to determine the temperature at 4000 feet.

**EDUCATION** For Exercises 49–51, use the following information.

The National Assessment of Educational Progress tests 4th, 8th, and 12th graders in the United States. The average math test scores for 17-year-olds can be represented as a function of the science scores by \( f(s) = 0.8s + 72 \), where \( f(s) \) is the math score and \( s \) is the science score.

49. Graph this function.
50. What is the science score that corresponds to a math score of 308?
51. Krista scored 260 in science and 320 in math. How does her math score compare to the average score of other students who scored 260 in science? Explain your answer.

52. **CRITICAL THINKING** State whether the following is sometimes, always, or never true.

The inverse of a function is also a function.
53. **Writing in Math** Answer the question that was posed at the beginning of the lesson.

How are functions used in meteorology?

Include the following in your answer:
- a description of the relationship between pressure and temperature, and
- an explanation of whether the relation is a function.

54. If \( f(x) = 20 - 2x \), find \( f(7) \).
   - A 6  
   - B 7  
   - C 13  
   - D 14

55. If \( f(x) = 2x \), which of the following statements must be true?
   I. \( f(3x) = 3[f(x)] \)
   II. \( f(x + 3) = f(x) + 3 \)
   III. \( f(x^2) = [f(x)]^2 \)
   - A I only  
   - B II only  
   - C I and II only  
   - D I, II, and III

**Maintain Your Skills**

**Mixed Review**

Graph each equation.  (Lesson 4-5)

56. \( y = x + 3 \)  
57. \( y = 2x - 4 \)  
58. \( 2x + 5y = 10 \)

Find the solution set for each equation, given the replacement set.  (Lesson 4-4)

59. \( y = 5x - 3 \); \{ (3, 12), (1, -2), (-2, -7), (-1, -8) \}  
60. \( y = 2x + 6 \); \{ (3, 0), (-1, 4), (6, 0), (5, -1) \}

61. **Running** Adam is training for an upcoming 26-mile marathon. He can run a 10K race (about 6.2 miles) in 45 minutes. If he runs the marathon at the same pace, how long will it take him to finish?  (Lesson 3-6)

Name the property used in each equation. Then find the value of \( n \).  (Lesson 1-4)

62. \( 16 = n + 16 \)  
63. \( 3.5 + 6 = n + 6 \)  
64. \( \frac{3}{5}n = \frac{3}{5} \)

**Getting Ready for the Next Lesson**

**Prerequisite Skill** Find each difference.  (To review subtracting integers, see Lesson 2-2.)

65. \( 12 - 16 \)  
66. \( -5 - (-8) \)  
67. \( 16 - (-4) \)

68. \( -9 - 6 \)  
69. \( \frac{3}{4} - \frac{1}{8} \)  
70. \( \frac{3}{2} - \left(-\frac{2}{3}\right) \)

**Practice Quiz 2**

Solve each equation if the domain is \(-3, -1, 0, 2, 4\).  (Lesson 4-4)

1. \( y = x + 5 \)  
2. \( y = 3x + 4 \)  
3. \( x + 2y = 8 \)

Graph each equation.  (Lesson 4-5)

4. \( y = x - 2 \)  
5. \( 3x + 2y = 6 \)

Determine whether each relation is a function.  (Lesson 4-6)

6. \{ (3, 4), (5, 3), (-1, 4), (6, 2) \}  
7. \{ (-1, 4), (-2, 5), (7, 2), (3, 9), (-2, 1) \}

If \( f(x) = 3x + 5 \), find each value.  (Lesson 4-6)

8. \( f(-4) \)  
9. \( f(2a) \)  
10. \( f(x + 2) \)
A Preview of Lesson 4-7

Number Sequences

You can use a spreadsheet to generate number sequences and patterns. The simplest type of sequence is one in which the difference between successive terms is constant. This type of sequence is called an arithmetic sequence.

Example

Use a spreadsheet to generate a sequence of numbers from an initial value of 10 to 90 with a fixed interval of 8.

Step 1 Enter the initial value 10 in cell A1.

Step 2 Highlight the cells in column A. Under the Edit menu, choose the Fill option and then Series.

Step 3 A command box will appear on the screen asking for the Step value and the Stop value. The Step value is the fixed interval between each number, which in this case is 8. The Stop value is the last number in your sequence, 90. Enter these numbers and click OK. The column is filled with the numbers in the sequence from 10 to 90 at intervals of 8.

Exercises

For Exercises 1–5, use a sequence of numbers from 7 to 63 with a fixed interval of 4.

1. Use a spreadsheet to generate the sequence. Write the numbers in the sequence.

2. How many numbers are in the sequence?

MAKED A CONJECTURE Let $a_n$ represent each number in a sequence if $n$ is the position of the number in the sequence. For example, $a_1 =$ the first number in the sequence, $a_2 =$ the second number, $a_3 =$ the third number, and so on.

3. Write a formula for $a_2$ in terms of $a_1$. Write similar formulas for $a_3$ and $a_4$ in terms of $a_1$.

4. Look for a pattern. Write an equation that can be used to find the $n$th term of a sequence.

5. Use the equation from Exercise 4 to find the 21st term in the sequence.
Arithmetic Sequences

What You’ll Learn

• Recognize arithmetic sequences.
• Extend and write formulas for arithmetic sequences.

Vocabulary

• sequence
• terms
• arithmetic sequence
• common difference

How are arithmetic sequences used to solve problems in science?

A probe to measure air quality is attached to a hot-air balloon. The probe has an altitude of 6.3 feet after the first second, 14.5 feet after the next second, 22.7 feet after the third second, and so on. You can make a table and look for a pattern in the data.

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude (ft)</td>
<td>6.3</td>
<td>14.5</td>
<td>22.7</td>
<td>30.9</td>
<td>39.1</td>
<td>47.3</td>
<td>55.5</td>
<td>63.7</td>
</tr>
</tbody>
</table>

This is an arithmetic sequence because the difference between terms is constant.

RECOGNIZE ARITHMETIC SEQUENCES

A sequence is a set of numbers in a specific order. The numbers in the sequence are called terms. If the difference between successive terms is constant, then it is called an arithmetic sequence. The difference between the terms is called the common difference.

Key Concept

An arithmetic sequence is a numerical pattern that increases or decreases at a constant rate or value called the common difference.

Example 1 Identify Arithmetic Sequences

Determine whether each sequence is arithmetic. Justify your answer.

a. 1, 2, 4, 8, …

1 + 1 = 2
2 + 2 = 4
4 + 4 = 8

This is an arithmetic sequence because the difference between terms is constant.

b. \(\frac{1}{2}, \frac{1}{4}, 0, -\frac{1}{4}, \ldots\)

\(\frac{1}{2} + \frac{1}{2} = \frac{1}{4}\)
\(\frac{1}{4} + \frac{1}{4} = 0\)
\(0 + \frac{1}{4} = -\frac{1}{4}\)

This is an arithmetic sequence because the difference between terms is constant.
WRITE ARITHMETIC SEQUENCES  You can use the common difference of an arithmetic sequence to find the next term in the sequence.

**Key Concept**

<table>
<thead>
<tr>
<th>Writing Arithmetic Sequences</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Words</strong>  Each term of an arithmetic sequence after the first term can be found by adding the common difference to the preceding term.</td>
</tr>
</tbody>
</table>
| **Symbols** An arithmetic sequence can be found as follows  
\[ a_1, a_1 + d, a_2 + d, a_3 + d, \ldots, \]
where \( d \) is the common difference, \( a_1 \) is the first term, \( a_2 \) is the second term, and so on. |

**Example 2**  Extend a Sequence

Find the next three terms of the arithmetic sequence 74, 67, 60, 53, ...

Find the common difference by subtracting successive terms.

\[
\begin{align*}
74 & \quad 67 & \quad 60 & \quad 53 & \quad ? & \quad ? & \quad ? \\
-7 & \quad -7 & \quad -7 & \quad -7 & \quad -7 & \quad -7 & \quad -7
\end{align*}
\]

The common difference is \(-7\).

Add \(-7\) to the last term of the sequence to get the next term in the sequence. Continue adding \(-7\) until the next three terms are found.

\[
\begin{align*}
53 & \quad 46 & \quad 39 & \quad 32 \\
-7 & \quad -7 & \quad -7
\end{align*}
\]

The next three terms are 46, 39, 32.

Each term in an arithmetic sequence can be expressed in terms of the first term \(a_1\) and the common difference \(d\).

<table>
<thead>
<tr>
<th>Term</th>
<th>Symbol</th>
<th>In Terms of (a_1) and (d)</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>first term</td>
<td>(a_1)</td>
<td>(a_1)</td>
<td>8</td>
</tr>
<tr>
<td>second term</td>
<td>(a_2)</td>
<td>(a_1 + d)</td>
<td>(8 + 1(3) = 11)</td>
</tr>
<tr>
<td>third term</td>
<td>(a_3)</td>
<td>(a_1 + 2d)</td>
<td>(8 + 2(3) = 14)</td>
</tr>
<tr>
<td>fourth term</td>
<td>(a_4)</td>
<td>(a_1 + 3d)</td>
<td>(8 + 3(3) = 17)</td>
</tr>
<tr>
<td>(\vdots)</td>
<td>(\vdots)</td>
<td>(\vdots)</td>
<td>(\vdots)</td>
</tr>
<tr>
<td>(n)th term</td>
<td>(a_n)</td>
<td>(a_1 + (n - 1)d)</td>
<td>(8 + (n - 1)(3))</td>
</tr>
</tbody>
</table>

The following formula generalizes this pattern and can be used to find any term in an arithmetic sequence.

**Key Concept**

**nth Term of an Arithmetic Sequence**

The \(n\)th term \(a_n\) of an arithmetic sequence with first term \(a_1\) and common difference \(d\) is given by

\[a_n = a_1 + (n - 1)d,\]

where \(n\) is a positive integer.
Example 3  Find a Specific Term

Find the 14th term in the arithmetic sequence 9, 17, 25, 33, ...

In this sequence, the first term, \(a_1\), is 9. You want to find the 14th term, so \(n = 14\).

Find the common difference.

\[
\begin{align*}
9 & \quad 17 \\
+8 & \quad +8 \\
25 & \quad 33
\end{align*}
\]

The common difference is 8.

Use the formula for the \(n\)th term of an arithmetic sequence.

\[
a_n = a_1 + (n - 1)d \quad \text{Formula for the } n\text{th term}
\]

\[
a_{14} = 9 + (14 - 1)8 \\
a_{14} = 9 + 104 \\
a_{14} = 113
\]

The 14th term in the sequence is 113.

Example 4  Write an Equation for a Sequence

Consider the arithmetic sequence 12, 23, 34, 45, ...

a. Write an equation for the \(n\)th term of the sequence.

In this sequence, the first term, \(a_1\), is 12. Find the common difference.

\[
\begin{align*}
12 & \quad 23 \\
+11 & \quad +11 \\
34 & \quad 45
\end{align*}
\]

The common difference is 11.

Use the formula for the \(n\)th term to write an equation.

\[
a_n = a_1 + (n - 1)d \quad \text{Formula for nth term}
\]

\[
a_n = 12 + (n - 1)11 \\
a_n = 12 + 11n - 11
\]

\[
\text{Simplify.}
\]

\[
a_n = 11n + 1
\]

CHECK

For \(n = 1\), 11(1) + 1 = 12.

For \(n = 2\), 11(2) + 1 = 23.

For \(n = 3\), 11(3) + 1 = 34, and so on.

b. Find the 10th term in the sequence.

Replace \(n\) with 10 in the equation written in part a.

\[
a_n = 11n + 1 \quad \text{Equation for the } n\text{th term}
\]

\[
a_{10} = 11(10) + 1 \quad \text{Replace } n \text{ with } 10.
\]

\[
a_{10} = 111 \quad \text{Simplify.}
\]

c. Graph the first five terms of the sequence.

<table>
<thead>
<tr>
<th>(n)</th>
<th>11(n + 1)</th>
<th>(a_n)</th>
<th>((n, a_n))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11(1) + 1</td>
<td>12</td>
<td>(1, 12)</td>
</tr>
<tr>
<td>2</td>
<td>11(2) + 1</td>
<td>23</td>
<td>(2, 23)</td>
</tr>
<tr>
<td>3</td>
<td>11(3) + 1</td>
<td>34</td>
<td>(3, 34)</td>
</tr>
<tr>
<td>4</td>
<td>11(4) + 1</td>
<td>45</td>
<td>(4, 45)</td>
</tr>
<tr>
<td>5</td>
<td>11(5) + 1</td>
<td>56</td>
<td>(5, 56)</td>
</tr>
</tbody>
</table>

Notice that the points fall on a line. The graph of an arithmetic sequence is linear.
1. **OPEN ENDED** Write an arithmetic sequence whose common difference is \(-10\).

2. **Find** the common difference and the first term in the sequence defined by \(a_n = 5n + 2\).

3. **FIND THE ERROR** Marisela and Richard are finding the common difference for the arithmetic sequence \(-44, -32, -20, -8\).

<table>
<thead>
<tr>
<th>Marisela</th>
<th>Richard</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-32 - (-44) = 12)</td>
<td>(-44 - (-32) = -12)</td>
</tr>
<tr>
<td>(-20 - (-32) = 12)</td>
<td>(-52 - (-20) = -12)</td>
</tr>
<tr>
<td>(-8 - (-20) = 12)</td>
<td>(-20 - (-8) = -12)</td>
</tr>
</tbody>
</table>

Who is correct? Explain your reasoning.

4. **GUIDE** Determine whether each sequence is an arithmetic sequence. If it is, state the common difference.

   4. 24, 16, 8, 0, …
   5. 3, 6, 12, 24, …

5. **FIND THE NEXT THREE TERMS** of each arithmetic sequence.

   6. 7, 14, 21, 28, …
   7. 34, 29, 24, 19, …

6. **FIND THE \(n\)TH TERM** of each arithmetic sequence described.

   8. \(a_1 = 3, d = 4, n = 8\)
   9. \(a_1 = 10, d = -5, n = 21\)
   10. 23, 25, 27, 29, … for \(n = 12\)
   11. \(-27, -19, -11, -3, \ldots\) for \(n = 17\)

7. **WRITE AN EQUATION** for the \(n\)th term of each arithmetic sequence. Then graph the first five terms of the sequence.

   12. 6, 12, 18, 24, …
   13. 12, 17, 22, 27, …

8. **FITNESS** Latisha is beginning an exercise program that calls for 20 minutes of walking each day for the first week. Each week thereafter, she has to increase her walking by 7 minutes a day. Which week of her exercise program will be the first one in which she will walk over an hour a day?
Find the $n$th term of each arithmetic sequence described.

27. $a_1 = 5, d = 5, n = 25$
28. $a_1 = 8, d = 3, n = 16$
29. $a_1 = 52, d = 12, n = 102$
30. $a_1 = 34, d = 15, n = 200$
31. $a_1 = \frac{5}{8}, d = \frac{1}{8}, n = 22$
32. $a_1 = \frac{1}{2}, d = 2\frac{1}{4}, n = 39$
33. $-9, -7, -5, -3, \ldots$ for $n = 18$
34. $-7, -3, 1, 5, \ldots$ for $n = 35$
35. $0.5, 1.5, 2, \ldots$ for $n = 50$
36. $5.3, 5.9, 6.5, 7.1, \ldots$ for $n = 12$

37. 200 is the ___ th term of 24, 35, 46, 57, ___
38. $-34$ is the ___ th term of 30, 22, 14, 6, ___

Write an equation for the $n$th term of each arithmetic sequence. Then graph the first five terms in the sequence.

39. $-3, -6, -9, -12, \ldots$
40. $8, 9, 10, 11, \ldots$
41. $2, 8, 14, 20, \ldots$
42. $-18, -16, -14, -12, \ldots$

43. Find the value of $y$ that makes $y, 4, y, \ldots$ an arithmetic sequence.
44. Find the value of $y$ that makes $y, 8, 4y, 6, 3y, \ldots$ an arithmetic sequence.

**GEOMETRY** For Exercises 45 and 46, use the diagram below that shows the perimeter of the pattern consisting of trapezoids.

45. Write a formula that can be used to find the perimeter of a pattern containing $n$ trapezoids.
46. What is the perimeter of the pattern containing 12 trapezoids?

**THEATER** For Exercises 47–49, use the following information.
The Coral Gables Actors’ Playhouse has 76 seats in the last row of the orchestra section of the theater, 68 seats in the next row, 60 seats in the next row, and so on. There are 7 rows of seats in the section. On opening night, 368 tickets were sold for the orchestra section.

47. Write a formula to find the number of seats in any given row of the orchestra section of the theater.
48. How many seats are in the first row?
49. Was this section oversold?

**PHYSICAL SCIENCE** For Exercises 50–53, use the following information.
Taylor and Brooklyn are recording how far a ball rolls down a ramp during each second. The table below shows the data they have collected.

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance traveled (cm)</td>
<td>9</td>
<td>13</td>
<td>17</td>
<td>21</td>
<td>25</td>
<td>29</td>
</tr>
</tbody>
</table>

50. Do the distances traveled by the ball form an arithmetic sequence? Justify your answer.
51. Write an equation for the sequence.
52. How far will the ball travel during the 35th second?
53. Graph the sequence.
GAMES  For Exercises 54 and 55, use the following information.
Contestants on a game show win money by answering 10 questions. The value of each question increases by $1500.

54. If the first question is worth $2500, find the value of the 10th question.
55. If the contestant answers all ten questions correctly, how much money will he or she win?

56. CRITICAL THINKING  Is 2x + 5, 4x + 5, 6x + 5, 8x + 5 … an arithmetic sequence? Explain your answer.

57. CRITICAL THINKING  Use an arithmetic sequence to find how many multiples of 7 are between 29 and 344.

58. WRITING IN MATH  Answer the question that was posed at the beginning of the lesson.
How are arithmetic sequences used to solve problems in science?
Include the following in your answer:
• a formula for the arithmetic sequence that represents the altitude of the probe after each second, and
• an explanation of how you could use this information to predict the altitude of the probe after 15 seconds.

59. Luis puts $25 a week into a savings account from his part-time job. If he has $350 in savings now, how much will he have 12 weeks from now?

60. In an arithmetic sequence \( a_n \), if \( a_1 = 2 \) and \( a_4 = 11 \), find \( a_{20} \).

Standardized Test Practice

59. Luis puts $25 a week into a savings account from his part-time job. If he has $350 in savings now, how much will he have 12 weeks from now?

   A $600  
   B $625  
   C $650  
   D $675

60. In an arithmetic sequence \( a_n \), if \( a_1 = 2 \) and \( a_4 = 11 \), find \( a_{20} \).

   A 40  
   B 59  
   C 78  
   D 97

Maintain Your Skills

Mixed Review

If \( f(x) = 3x - 2 \) and \( g(x) = x^2 - 5 \), find each value.  

61. \( f(4) \)  
62. \( g(-3) \)  
63. \( 2f(6) \)

Determine whether each equation is a linear equation. If so, write the equation in standard form.

64. \( x^2 + 3x - y = 8 \)  
65. \( y - 8 = 10 - x \)  
66. \( 2y = y + 2x - 3 \)

Translate each sentence into an algebraic equation.

67. Two hundred minus three times \( x \) is equal to nine.
68. The sum of twice \( r \) and three times \( s \) is identical to thirteen.

Find each product.

69. \( 7(-3) \)  
70. \(-11 \cdot 15\)  
71. \(-8(-1.5)\)

72. \( \frac{2}{3} \)  
73. \( \left(-\frac{5}{8}\right)\left(\frac{4}{7}\right)\)  
74. \( 5 \cdot 3\frac{1}{2} \)

Getting Ready for the Next Lesson

PREREQUISITE SKILL  Write the ordered pair for each point shown at the right.

75. \( H \)  
76. \( J \)  
77. \( K \)  
78. \( L \)  
79. \( M \)  
80. \( N \)
Throughout your life, you have used reasoning skills, possibly without even knowing it. As a child, you used inductive reasoning to conclude that your hand would hurt if you touched the stove while it was hot. Now, you use inductive reasoning when you decide, after many trials, that one of the worst ways to prepare for an exam is by studying only an hour before you take it. **Inductive reasoning** is used to derive a general rule after observing many individual events.

Inductive reasoning involves . . .
- observing many examples
- looking for a pattern
- making a conjecture
- checking the conjecture
- discovering a likely conclusion

With **deductive reasoning**, you use a general rule to help you decide about a specific event. You come to a conclusion by accepting facts. There is no conjecturing involved. Read the two statements below.

1) If a person wants to play varsity sports, he or she must have a C average in academic classes.

2) Jolene is playing on the varsity tennis team.

If these two statements are accepted as facts, then the obvious conclusion is that Jolene has at least a C average in her academic classes. This is an example of deductive reasoning.

**Reading to Learn**

1. Explain the difference between *inductive* and *deductive* reasoning. Then give an example of each.

2. When Sherlock Holmes reaches a conclusion about a murderer’s height because he knows the relationship between a man’s height and the distance between his footprints, what kind of reasoning is he using? Explain.

3. When you examine a sequence of numbers and decide that it is an arithmetic sequence, what kind of reasoning are you using? Explain.

4. Once you have found the common difference for an arithmetic sequence, what kind of reasoning do you use to find the 100th term in the sequence?

5. **a.** Copy and complete the following table.

<table>
<thead>
<tr>
<th></th>
<th>3^1</th>
<th>3^2</th>
<th>3^3</th>
<th>3^4</th>
<th>3^5</th>
<th>3^6</th>
<th>3^7</th>
<th>3^8</th>
<th>3^9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>9</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**b.** Write the sequence of numbers representing the numbers in the ones place.

**c.** Find the number in the ones place for the value of 3^{100}. Explain your reasoning. State the type of reasoning that you used.

6. A sequence contains all numbers less than 50 that are divisible by 5. You conclude that 35 is in the sequence. Is this an example of inductive or deductive reasoning? Explain.
LOOK FOR PATTERNS  A very useful problem-solving strategy is look for a pattern. When you make a conclusion based on a pattern of examples, you are using inductive reasoning. Recall that deductive reasoning uses facts, rules, or definitions to reach a conclusion.

**Example 1  Extend a Pattern**

Study the pattern below.

![Pattern](image)

a. Draw the next three figures in the pattern.

The pattern consists of circles with one-fourth shaded. The section that is shaded is rotated in a clockwise direction. The next three figures are shown.

![Next Three Figures](image)
b. Draw the 27th circle in the pattern.

The pattern repeats every fourth design. Therefore designs 4, 8, 12, 16, and so on, will all be the same. Since 24 is the greatest number less than 27 that is a multiple of 4, the 25th circle in the pattern will be the same as the first circle.

Other sequences besides arithmetic sequences can follow a pattern.

**Example 2 Patterns in a Sequence**

Find the next three terms in the sequence 3, 6, 12, 24, … .

Study the pattern in the sequence.

\[ \begin{array}{cccc}
3 & 6 & 12 & 24 \\
+3 & +6 & +12 & \\
\end{array} \]

You can use inductive reasoning to find the next term in a sequence. Notice the pattern 3, 6, 12, … The difference between each term doubles in each successive term. To find the next three terms in the sequence, continue doubling each successive difference. Add 24, 48, and 96.

\[ \begin{array}{cccc}
3 & 6 & 12 & 24 & 48 & 96 & 192 \\
+3 & +6 & +12 & +24 & +48 & +96 & \\
\end{array} \]

The next three terms are 48, 96, and 192.

**Algebra Activity**

**Looking for Patterns**

- You will need several pieces of string.
- Loop a piece of string around one of the cutting edges of the scissors and cut. How many pieces of string do you have as a result of this cut? Discard those pieces.
- Use another piece of string to make 2 loops around the scissors and cut. How many pieces of string result?
- Continue making loops and cutting until you see a pattern.

**Analyze**

1. Describe the pattern and write a sequence that describes the number of loops and the number of pieces of string.
2. Write an expression that you could use to find the number of pieces of string you would have if you made \( n \) loops.
3. How many pieces of string would you have if you made 20 loops?

**WRITE EQUATIONS** Sometimes a pattern can lead to a general rule. If the relationship between the domain and range of a relation is linear, the relationship can be described by a linear equation.
**Example 3** Write an Equation from Data

**FUEL ECONOMY** The table below shows the average amount of gas Rogelio’s car uses depending on how many miles he drives.

<table>
<thead>
<tr>
<th>Gallons of gasoline</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miles driven</td>
<td>28</td>
<td>56</td>
<td>84</td>
<td>112</td>
<td>140</td>
</tr>
</tbody>
</table>

a. Graph the data. What conclusion can you make about the relationship between the number of gallons used and the number of miles driven?

The graph shows a linear relationship between the number of gallons used \( g \) and the number of miles driven \( m \).

b. Write an equation to describe this relationship.

Look at the relationship between the domain and range to find a pattern that can be described by an equation.

Since this is a linear relationship, the ratio of the range values to the domain values is constant. The difference of the values for \( g \) is 1, and the difference of the values for \( m \) is 28. This suggests that \( m = 28g \). Check to see if this equation is correct by substituting values of \( g \) into the equation.

**CHECK**
- If \( g = 1 \), then \( m = 28(1) \) or 28. √
- If \( g = 2 \), then \( m = 28(5) \) or 56. √
- If \( g = 3 \), then \( m = 28(3) \) or 84. √

The equation checks. Since this relation is also a function, we can write the equation as \( f(g) = 0.28g \), where \( f(g) \) represents the number of miles driven.

**Example 4** Write an Equation with a Constant

Write an equation in function notation for the relation graphed at the right.

Make a table of ordered pairs for several points on the graph.

The difference of the \( x \) values is 1, and the difference of the \( y \) values is 2. The difference in \( y \) values is twice the difference of \( x \) values. This suggests that \( y = 2x \). Check this equation.
1. Explain how you can use inductive reasoning to write an equation from a pattern.

2. OPEN ENDED Write a sequence for which the first term is 4 and the second term is 8. Explain the pattern that you used.

3. Explain how you can determine whether an equation correctly represents a relation given in a table.

4. Find the next two items for the pattern. Then find the 16th figure in the pattern.

5. 1, 2, 4, 7, 11, ...

6. 5, 9, 6, 10, 7, 11, ...

Write an equation in function notation for each relation.

7. 

8. 

Application GEOLOGY For Exercises 9–11, use the table below that shows the underground temperature of rocks at various depths below Earth’s surface.

<table>
<thead>
<tr>
<th>Depth (km)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>55</td>
<td>90</td>
<td>125</td>
<td>160</td>
<td>195</td>
<td>230</td>
</tr>
</tbody>
</table>

9. Graph the data.

10. Write an equation in function notation for the relation.

11. Find the temperature of a rock that is 10 kilometers below the surface.
Practice and Apply

Find the next two items for each pattern. Then find the 21st figure in the pattern.

12. \[ \ldots \]

13. \[ \ldots \]

Find the next three terms in each sequence.

14. \[ 0, 2, 6, 12, 20, \ldots \]

15. \[ 9, 7, 10, 8, 11, 9, 12, \ldots \]

16. \[ 1, 4, 9, 16, \ldots \]

17. \[ 0, 2, 5, 9, 14, 20, \ldots \]

18. \[ a, a + 1, a + 2, a + 3, \ldots \]

19. \[ x, 2x + 1, 3x + 1, \ldots \]

Write an equation in function notation for each relation.

20. \[
\begin{array}{c}
\text{y} \\
\text{x}
\end{array}
\]

21. \[
\begin{array}{c}
\text{y} \\
\text{x}
\end{array}
\]

22. \[
\begin{array}{c}
\text{y} \\
\text{x}
\end{array}
\]

23. \[
\begin{array}{c}
\text{y} \\
\text{x}
\end{array}
\]

24. \[
\begin{array}{c}
\text{y} \\
\text{x}
\end{array}
\]

25. \[
\begin{array}{c}
\text{y} \\
\text{x}
\end{array}
\]

26. **TRAVEL** On an island cruise in Hawaii, each passenger is given a flower chain. A crew member hands out 3 red, 3 blue, and 3 green chains in that order. If this pattern is repeated, what color chain will the 50th person receive?

**Number Theory**

Fibonacci numbers occur in many areas of nature, including pine cones, shell spirals, flower petals, branching plants, and many fruits and vegetables.

For Exercises 27 and 28, use the following information.

In 1201, Leonardo Fibonacci introduced his now famous pattern of numbers called the Fibonacci sequence.

\[ 1, 1, 2, 3, 5, 8, 13, \ldots \]

Notice the pattern in this sequence. After the second number, each number in the sequence is the sum of the two numbers that precede it. That is \( 2 = 1 + 1 \), \( 3 = 2 + 1 \), \( 5 = 3 + 2 \), and so on.

27. Write the first 12 terms of the Fibonacci sequence.

28. Notice that every third term is divisible by 2. What do you notice about every fourth term? every fifth term?
FITNESS  For Exercises 29 and 30, use the table below that shows the maximum heart rate to maintain, for different ages, during aerobic activities such as running, biking, or swimming.

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse rate (beats/min)</td>
<td>175</td>
<td>166</td>
<td>157</td>
<td>148</td>
<td>139</td>
<td>130</td>
</tr>
</tbody>
</table>

Source: Ontario Association of Sport and Exercise Sciences

29. Write an equation in function notation for the relation.
30. What would be the maximum heart rate to maintain in aerobic training for a 10-year old? an 80-year old?

CRITICAL THINKING  For Exercises 31–33, use the following information.
Suppose you arrange a number of regular pentagons so that only one side of each pentagon touches. Each side of each pentagon is 1 centimeter.

1 pentagon  2 pentagons  3 pentagons  4 pentagons

31. For each arrangement of pentagons, compute the perimeter.
32. Write an equation in function form to represent the perimeter $f(n)$ of $n$ pentagons.
33. What is the perimeter if 24 pentagons are used?

34. **WRITING IN MATH**  Answer the question that was posed at the beginning of the lesson.

**Why is writing equations from patterns important in science?**
Include the following in your answer:

- an explanation of the relationship between the volume of water and the volume of ice, and

- a reasonable estimate of the size of a container that had 99 cubic feet of water, if it was going to be frozen.

35. Find the next two terms in the sequence 3, 4, 6, 9, … .
   - A  12, 15  
   - B  13, 18  
   - C  14, 19  
   - D  15, 21

36. After $P$ pieces of candy are divided equally among 5 children, 4 pieces remain. How many would remain if $P + 4$ pieces of candy were divided equally among the 5 children?
   - A  0  
   - B  1  
   - C  2  
   - D  3

Mixed Review  Find the next three terms of each arithmetic sequence.  
37. 1, 4, 7, 10, …  
38. 9, 5, 1, −3, …  
39. −25, −19, −13, −7, …  
40. 22, 34, 46, 58, …  
41. Determine whether the relation graphed at the right is a function.  
42. **GEOGRAPHY**  The world’s tallest waterfall is Angel Falls in Venezuela at 3212 feet. It is 102 feet higher than Tulega Falls in South Africa. How high is Tulega Falls?  

www.algebra1.com/self_check_quiz
The Coordinate Plane

Concept Summary
- The first number, or x-coordinate, corresponds to the numbers on the x-axis.
- The second number, or y-coordinate, corresponds to the numbers on the y-axis.

Example
Plot T(3, −2) on a coordinate plane. Name the quadrant in which the point is located.

T(3, −2) is located in Quadrant IV.

Exercises
- Plot each point on a coordinate plane. See Example 3 on page 193.

11. A(4, 2)
12. B(−1, 3)
13. C(0, −5)
14. D(−3, −2)
15. E(−4, 0)
16. F(2, −1)

Choose the letter of the term that best matches each statement or phrase.
1. In the coordinate plane, the axes intersect at the ___.
2. A(n) __ is a set of ordered pairs.
3. A(n) __ flips a figure over a line.
4. In a coordinate system, the __ is a horizontal number line.
5. In the ordered pair, A(2, 7), 7 is the __.
6. The coordinate axes separate a plane into four __.
7. A(n) __ has a graph that is a nonvertical straight line.
8. In the relation {(4, −2), (0, 5), (6, 2), (−1, 8)}, the __ is {−1, 0, 4, 6}.
9. A(n) __ enlarges or reduces a figure.
10. In a coordinate system, the __ is a vertical number line.

a. domain  b. dilation  c. linear function  d. reflection  e. origin  f. quadrants  g. relation  h. x-axis  i. y-axis  j. x-coordinate  k. y-coordinate
4-2

Transformations on the Coordinate Plane

Concept Summary
- A reflection is a flip.
- A translation is a slide.
- A dilation is a reduction or enlargement.
- A rotation is a turn.

Example
A quadrilateral with vertices W(1, 2), X(2, 3), Y(5, 2), and Z(2, 1) is reflected over the y-axis. Find the coordinates of the vertices of the image. Then graph quadrilateral WXYZ and its image W’X’Y’Z’.

Multiply each x-coordinate by –1.

\[ W(1, 2) \rightarrow W'(−1, 2) \quad Y(5, 2) \rightarrow Y'(−5, 2) \]

\[ X(2, 3) \rightarrow X'(−2, 3) \quad Z(2, 1) \rightarrow Z'(−2, 1) \]

The coordinates of the image are W'(−1, 2), X'(−2, 3), Y'(−5, 2), and Z'(−2, 1).

Exercises
Find the coordinates of the vertices of each figure after the given transformation is performed. Then graph the preimage and its image.

17. triangle ABC with A(3, 3), B(5, 4), and C(4, −3) reflected over the x-axis
18. quadrilateral PQRS with P(−2, 4), Q(0, 6), R(3, 3), and S(1, 4) translated 3 units down
19. parallelogram GHIJ with G(2, 2), H(6, 0), I(6, 2), and J(2, 4) dilated by a scale factor of \( \frac{1}{2} \)
20. trapezoid MNOP with M(2, 0), N(4, 3), O(6, 3), and P(8, 0) rotated 90° counterclockwise about the origin

4-3

Relations

Concept Summary
- A relation can be expressed as a set of ordered pairs, a table, a graph, or a mapping.

Example
Express the relation \{(3, 2), (5, 3), (4, 3), (5, 2)\} as a table, a graph, and a mapping.

Table
List the set of x-coordinates and corresponding y-coordinates.

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>

Graph
Graph each ordered pair on a coordinate plane.

Mapping
List the x and y values. Draw arrows to show the relation.
### Equations as Relations

**Concept Summary**
- In an equation involving \(x\) and \(y\), the set of \(x\) values is the domain, and the corresponding set of \(y\) values is the range.

**Example**
Solve \(2x + y = 8\) if the domain is \{3, 2, 1\}. Graph the solution set.

First solve the equation for \(y\) in terms of \(x\).

\[
2x + y = 8 \quad \text{Original equation}
\]

\[
y = 8 - 2x \quad \text{Subtract 2x from each side.}
\]

Substitute each value of \(x\) from the domain to determine the corresponding values of \(y\) in the range.

Then graph the solution set \{(3, 2), (2, 4), (1, 6)\}.

<table>
<thead>
<tr>
<th>(x)</th>
<th>(8 - 2x)</th>
<th>(y)</th>
<th>((x, y))</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>8 - 2(3)</td>
<td>2</td>
<td>(3, 2)</td>
</tr>
<tr>
<td>2</td>
<td>8 - 2(2)</td>
<td>4</td>
<td>(2, 4)</td>
</tr>
<tr>
<td>1</td>
<td>8 - 2(1)</td>
<td>6</td>
<td>(1, 6)</td>
</tr>
</tbody>
</table>

**Exercises**
Solve each equation if the domain is \{-4, -2, 0, 2, 4\}. Graph the solution set. See Example 3 on page 213.

25. \(y = x - 9\)  
26. \(y = 4 - 2x\)  
27. \(4x - y = -5\)  
28. \(2x + y = 8\)  
29. \(3x + 2y = 9\)  
30. \(4x - 3y = 0\)

### Graphing Linear Equations

**Concept Summary**
- Standard form: \(Ax + By = C\), where \(A \geq 0\) and \(A\) and \(B\) are not both zero
- To find the \(x\)-intercept, let \(y = 0\). To find the \(y\)-intercept, let \(x = 0\).

**Example**
Determine the \(x\)- and \(y\)-intercepts of \(3x - y = 4\). Then graph the equation.

To find the \(x\)-intercept, let \(y = 0\).

\[
3x - y = 4 \quad \text{Original equation}
\]

\[
3x - 0 = 4 \quad \text{Replace \(y\) with 0.}
\]

\[
3x = 4 \quad \text{Simplify.}
\]

\[
x = \frac{4}{3} \quad \text{Divide each side by 3.}
\]

To find the \(y\)-intercept, let \(x = 0\).

\[
3x - y = 4 \quad \text{Original equation}
\]

\[
3(0) - y = 4 \quad \text{Replace \(x\) with 0.}
\]

\[
y = -4 \quad \text{Simplify.}
\]

\[
\frac{4}{3} \quad \text{Divide each side by } -1.
\]
Functions

Concept Summary

• A relation is a function if each element of the domain is paired with exactly one element of the range.

• Substitute values for \( x \) to determine \( f(x) \) for a specific value.

Exercises

Determine whether each relation is a function. See Examples 1 on page 226.

37. \( \{(0, -4), (1, -1), (2, 2), (6, 3)\} \) is a function.

38. \( \{(2, 3), (-3, -4), (-1, 3)\} \)

40. If \( g(x) = x^2 - x + 1 \), find each value. See Examples 3 and 4 on pages 227 and 228.

41. \( g(-1) \)

42. \( g\left(\frac{1}{2}\right) \)

43. \( g(5) - 3 \)

44. \( g(a + 1) \)

45. \( g(-2a) \)

Arithmetic Sequences

Concept Summary

• An arithmetic sequence is a numerical pattern that increases or decreases at a constant rate or value called the common difference.

• To find the next term in an arithmetic sequence, add the common difference to the last term.
4-8 Writing Equations from Patterns

Example

Find the next three terms of the arithmetic sequence 10, 23, 36, 49, ….

Find the common difference. Add 13 to the last term of the sequence to get the next term. Continue adding 13 until the next three terms are found.

\[
\begin{align*}
10 & \rightarrow 23 & \rightarrow 36 & \rightarrow 49 \\
+13 & & +13 & & +13
\end{align*}
\]

So, \(d = 13\).

The next three terms are 62, 75, and 88.

Exercises

Find the next three terms of each arithmetic sequence.

See Example 2 on page 234.

46. 9, 18, 27, 36, …
47. 6, 11, 16, 21, …
48. 10, 21, 32, 43, …
49. 14, 12, 10, 8, …
50. −3, −11, −19, −27, …
51. −35, −29, −23, −17, …

Example

Write an equation in function notation for the relation graphed at the right.

Make a table of ordered pairs for several points on the graph.

The difference in \(y\) values is twice the difference of \(x\) values. This suggests that \(y = 2x\). However, \(3 \neq 2(1)\). Compare the values of \(y\) to the values of \(2x\).

The difference between \(y\) and \(2x\) is always 1. So the equation is \(y = 2x + 1\). Since this relation is also a function, it can be written as \(f(x) = 2x + 1\).

Exercises

Write an equation in function notation for each relation.

See Example 4 on pages 242 and 243.

52. 

53. 

y is always 3 more than \(2x\).
Chapter 4 Practice Test

Vocabulary and Concepts
Choose the letter that best matches each description.
1. a figure turned around a point  
   a. reflection  
2. a figure slid horizontally, vertically, or both  
   b. rotation  
3. a figure flipped over a line  
   c. translation

Skills and Applications
4. Graph \( K(0, -5), M(3, -5), \) and \( N(-2, -3) \).
5. Name the quadrant in which \( P(25, 1) \) is located.

For Exercises 6 and 7, use the following information.
A parallelogram has vertices \( H(-2, -2), I(-4, -6), J(-5, -5), \) and \( K(-3, -1) \).
6. Reflect parallelogram \( HIJK \) over the \( y \)-axis and graph its image.
7. Translate parallelogram \( HIJK \) up 2 units and graph its image.

Express the relation shown in each table, mapping, or graph as a set of ordered pairs. Then write the inverse of the relation.

8. 

<table>
<thead>
<tr>
<th>( x )</th>
<th>( f(x) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
</tr>
</tbody>
</table>

9. 

\[ X \quad Y \]
\[ -1 \quad 2 \]
\[ -3 \quad -2 \]

10. 

Determine whether each relation is a function.
17. \( (2, 4), (3, 2), (4, 6), (5, 4) \)  
18. \( (3, 1), (2, 5), (4, 0), (3, -2) \)  
19. \( 8y = 7 + 3x \)

If \( f(x) = -2x + 5 \) and \( g(x) = x^2 - 4x + 1 \), find each value.
20. \( g(-2) \)  
21. \( f\left(\frac{1}{2}\right) \)  
22. \( g(3a) + 1 \)  
23. \( f(x + 2) \)

Determine whether each sequence is an arithmetic sequence. If it is, state the common difference.
24. 16, 24, 32, 40, …  
25. 99, 87, 76, 65, …  
26. 5, 17, 29, 41, …

Find the next three terms in each sequence.
27. 5, -10, 15, -20, 25, …  
28. 5, 5, 6, 8, 11, 15, …

29. TEMPERATURE  
   The equation to convert Celsius temperature to Kelvin temperature is \( K = C + 273 \). Solve the equation for \( C \). State the independent and dependent variables. Choose five values for \( K \) and their corresponding values for \( C \).

30. STANDARDIZED TEST PRACTICE  
   If \( f(x) = 3x - 2 \), find \( f(8) - f(-5) \).
   
   A 7  
   B 9  
   C 37  
   D 39

www.algebra1.com/chapter_test

Chapter 4 Practice Test 251
Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. The number of students in Highview School is currently 315. The school population is predicted to increase by 2% next year. According to the prediction, how many students will attend next year? (Prerequisite Skill)
   - A 317
   - B 321
   - C 378
   - D 630

2. In 2001, two women skied 1675 miles in 89 days across the land mass of Antarctica. They still had to ski 508 miles across the Ross Ice Shelf to reach McMurdo Station. About what percent of their total distance remained? (Prerequisite Skill)
   - A 2%
   - B 17%
   - C 23%
   - D 30%

3. Only 2 out of 5 students surveyed said they eat five servings of fruits or vegetables daily. If there are 470 students in a school, how many would you predict eat five servings of fruits or vegetables daily? (Lesson 2-6)
   - A 94
   - B 188
   - C 235
   - D 282

4. Solve $13x = 2(5x + 3)$ for $x$. (Lesson 3-4)
   - A 0
   - B 2
   - C 3
   - D 4

5. The circle shown below passes through points at $(1, 4), (-2, 1), (-5, 4)$, and $(-2, 7)$. Which point represents the center of the circle? (Lesson 4-1)
   - A $(-2, -4)$
   - B $(-2, 4)$
   - C $(-4, 2)$
   - D $(4, -2)$

6. Which value of $x$ would cause the relation $\{(2, 5), (x, 8), (7, 10)\}$ not to be a function? (Lesson 4-4)
   - A 1
   - B 2
   - C 5
   - D 8

7. Which ordered pair $(x, y)$ is a solution of $3x + 4y = 12$? (Lesson 4-4)
   - A $(-2, 4)$
   - B $(0, -3)$
   - C $(1, 2)$
   - D $(4, 0)$

8. Which missing value for $y$ would make this relation a linear relation? (Lesson 4-7)
   - A $-2$
   - B 0
   - C 1
   - D 2

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-3</td>
</tr>
<tr>
<td>2</td>
<td>-1</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>?</td>
</tr>
</tbody>
</table>

9. Which equation describes the data in the table? (Lesson 4-8)
   - A $y = -2x + 1$
   - B $y = x + 1$
   - C $y = -x + 3$
   - D $y = x - 5$

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>-1</td>
</tr>
<tr>
<td>6</td>
<td>-3</td>
</tr>
</tbody>
</table>
Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

10. The lengths of the corresponding sides of these two rectangles are proportional. What is the width \( w \)? (Lesson 2-6)

\[
\text{15 cm} \quad \begin{array}{c}
\text{w} \\
\text{4 cm}
\end{array}
\]

11. The PTA at Fletcher’s school sold raffle tickets for a television set. Two thousand raffle tickets were sold. Fletcher’s family bought 25 raffle tickets. What is the probability that his family will win the television? Express the answer as a percent. (Lesson 2-7)

12. The sum of three integers is 52. The second integer is 3 more than the first. The third integer is 1 more than twice the first. What are the integers? (Lessons 3-1 and 3-4)

13. Solve \( 5(x - 2) - 3(x + 4) = 10 \) for \( x \). (Lesson 3-4)

14. A CD player originally cost $160. It is now on sale for $120. What is the percent of decrease in its price? (Lesson 3-5)

15. A swimming pool holds 1800 cubic feet of water. It is 6 feet deep and 20 feet long. How many feet wide is the pool? \( V = \ell \times w \times h \) (Lesson 3-8)

16. Garth used toothpicks to form a pattern of triangles as shown below. If he continues this pattern, what is the total number of toothpicks that he will use to form a pattern of 7 triangles? (Lessons 4-7 and 4-8)

Part 3 Quantitative Comparison

Compare the quantity in Column A and in Column B. Then determine whether:

A the quantity in Column A is greater,
B the quantity in Column B is greater,
C the two quantities are equal, or
D the relationship cannot be determined from the information given.

<table>
<thead>
<tr>
<th>Column A</th>
<th>Column B</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 42 \div 16(2 + 5) \times 3 )</td>
<td>( 60 - 2^3 \times 3 + 6 \div 4^3 - 62 )</td>
</tr>
<tr>
<td>( \left( \frac{2}{3} \right) \left( \frac{15}{8} \right) \left( \frac{1}{9} \right) )</td>
<td>( \left( \frac{3}{4} \right) \left( \frac{1}{14} \right) )</td>
</tr>
<tr>
<td>( x ) if ( 6x - 15 = -3x + 75 )</td>
<td>( y ) if ( 3y - 32 = 7y - 74 )</td>
</tr>
<tr>
<td>( f(-10) ) if ( f(x) = 37 + 10x )</td>
<td>( g(-15) ) if ( g(x) = 9x - 7 )</td>
</tr>
</tbody>
</table>

Part 4 Open Ended

Record your answers on a sheet of paper. Show your work.

21. Latoya bought 48 one-foot-long sections of fencing. She plans to use the fencing to enclose a rectangular area for a garden. (Lesson 3-8)
   a. Using \( \ell \) for the length and \( w \) for the width of the garden, write an equation for its perimeter.
   b. If the length \( \ell \) in feet and width \( w \) in feet are whole numbers, what is the greatest possible area of this garden?