

2.4

Vertical Angles

Goal

Find the measures of angles formed by intersecting lines.

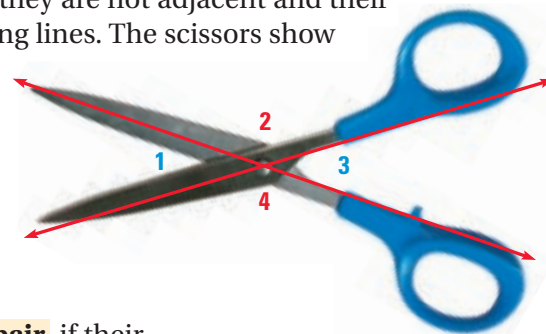
Key Words

- vertical angles
- linear pair

Two angles are **vertical angles** if they are not adjacent and their sides are formed by two intersecting lines. The scissors show two sets of vertical angles.

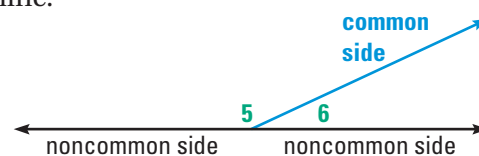
$\angle 1$ and $\angle 3$ are vertical angles.

$\angle 2$ and $\angle 4$ are vertical angles.



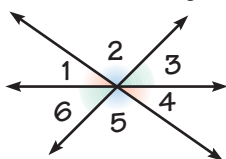
Two adjacent angles are a **linear pair** if their noncommon sides are on the same line.

$\angle 5$ and $\angle 6$ are a linear pair.



Visualize It!

You can use colored pencils to help you see pairs of vertical angles.



Vertical angles

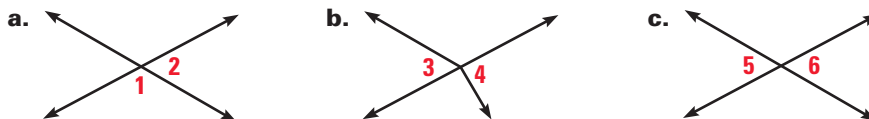
$\angle 1$ and $\angle 4$

$\angle 2$ and $\angle 5$

$\angle 3$ and $\angle 6$

EXAMPLE 1 Identify Vertical Angles and Linear Pairs

Determine whether the labeled angles are *vertical angles*, a *linear pair*, or *neither*.



Solution

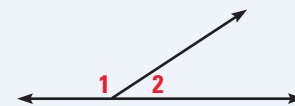
- $\angle 1$ and $\angle 2$ are a linear pair because they are adjacent and their noncommon sides are on the same line.
- $\angle 3$ and $\angle 4$ are neither vertical angles nor a linear pair.
- $\angle 5$ and $\angle 6$ are vertical angles because they are not adjacent and their sides are formed by two intersecting lines.

POSTULATE 7

Linear Pair Postulate

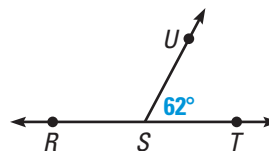
Words If two angles form a linear pair, then they are supplementary.

Symbols $m\angle 1 + m\angle 2 = 180^\circ$



EXAMPLE 2 Use the Linear Pair Postulate

Find the measure of $\angle RSU$.

**Solution**

$\angle RSU$ and $\angle UST$ are a linear pair. By the Linear Pair Postulate, they are supplementary. To find $m\angle RSU$, subtract $m\angle UST$ from 180° .

$$m\angle RSU = 180^\circ - m\angle UST = 180^\circ - 62^\circ = 118^\circ$$

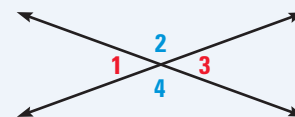
Student Help**VISUAL STRATEGY**

Draw an example of this theorem with specific measures, as shown on p. 52.

THEOREM 2.3**Vertical Angles Theorem**

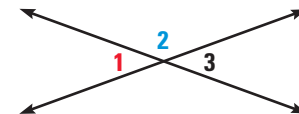
Words Vertical angles are congruent.

Symbols $\angle 1 \cong \angle 3$ and $\angle 2 \cong \angle 4$.

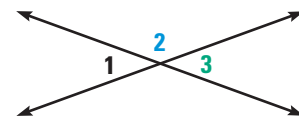


The following steps show why the Vertical Angles Theorem is true.

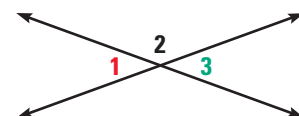
- ① $\angle 1$ and $\angle 2$ are a linear pair, so $\angle 1$ and $\angle 2$ are supplementary.



- ② $\angle 2$ and $\angle 3$ are a linear pair, so $\angle 2$ and $\angle 3$ are supplementary.



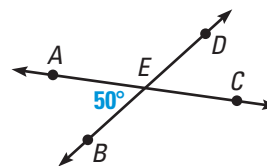
- ③ $\angle 1$ and $\angle 3$ are supplementary to the same angle, so $\angle 1$ is congruent to $\angle 3$ by the Congruent Supplements Theorem.

**Student Help****LOOK BACK**

To review the Congruent Supplements Theorem, see p. 69.

EXAMPLE 3 Use the Vertical Angles Theorem

Find the measure of $\angle CED$.

**Solution**

$\angle AEB$ and $\angle CED$ are vertical angles. By the Vertical Angles Theorem, $\angle CED \cong \angle AEB$, so $m\angle CED = m\angle AEB = 50^\circ$.

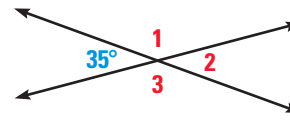
Student Help

STUDY TIP

When you know the measure of one vertical angle, an easy starting point is to fill in the measure of the other.

EXAMPLE 4 Find Angle Measures

Find $m\angle 1$, $m\angle 2$, and $m\angle 3$.



Solution

$$m\angle 2 = 35^\circ$$

Vertical Angles Theorem

$$m\angle 1 = 180^\circ - 35^\circ = 145^\circ$$

Linear Pair Postulate

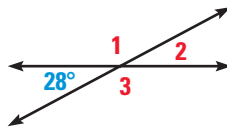
$$m\angle 3 = m\angle 1 = 145^\circ$$

Vertical Angles Theorem

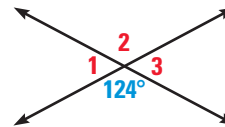
Checkpoint Find Angle Measures

Find $m\angle 1$, $m\angle 2$, and $m\angle 3$.

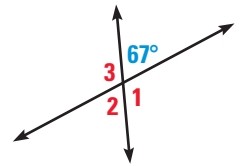
1.



2.



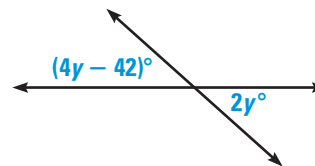
3.



Using Algebra

EXAMPLE 5 Use Algebra with Vertical Angles

Find the value of y .



Solution

Because the two expressions are measures of vertical angles, you can write the following equation.

$$(4y - 42)^\circ = 2y^\circ$$

Vertical Angles Theorem

$$4y - 42 - 4y = 2y - 4y$$

Subtract $4y$ from each side.

$$-42 = -2y$$

Simplify.

$$\frac{-42}{-2} = \frac{-2y}{-2}$$

Divide each side by -2 .

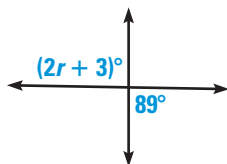
$$21 = y$$

Simplify.

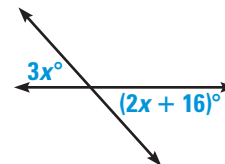
Checkpoint Use Algebra with Angle Measures

Find the value of the variable.

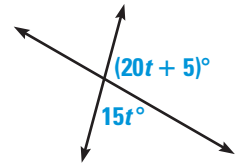
4.



5.



6.



2.4 Exercises

Guided Practice

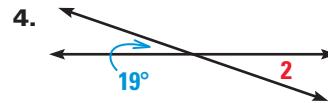
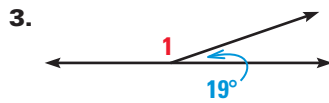
Vocabulary Check

Complete the statement.

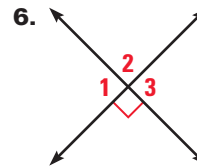
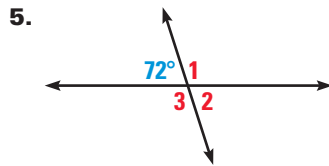
- Two adjacent angles whose noncommon sides are on the same line are called ?.
- Two angles are called ? if they are not adjacent and their sides are formed by two intersecting lines.

Skill Check

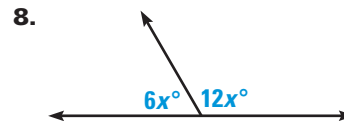
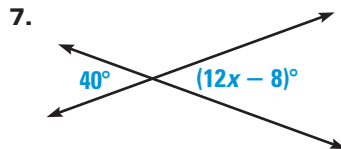
Find the measure of the numbered angle.



Find $m\angle 1$, $m\angle 2$, and $m\angle 3$.



Find the value of x .



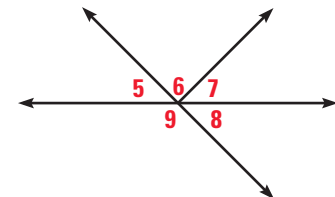
Practice and Applications

Extra Practice

See p. 678.

Vertical Angles and Linear Pairs Determine whether the angles are *vertical angles*, a *linear pair*, or *neither*.

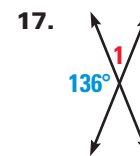
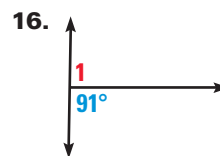
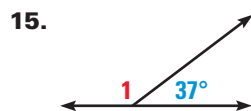
- | | |
|-------------------------------|-------------------------------|
| 9. $\angle 5$ and $\angle 6$ | 10. $\angle 5$ and $\angle 9$ |
| 11. $\angle 5$ and $\angle 8$ | 12. $\angle 6$ and $\angle 9$ |
| 13. $\angle 8$ and $\angle 9$ | 14. $\angle 5$ and $\angle 7$ |



Homework Help

- Example 1: Exs. 9–14
- Example 2: Exs. 15–19
- Example 3: Exs. 20–22
- Example 4: Exs. 28–37
- Example 5: Exs. 51–56

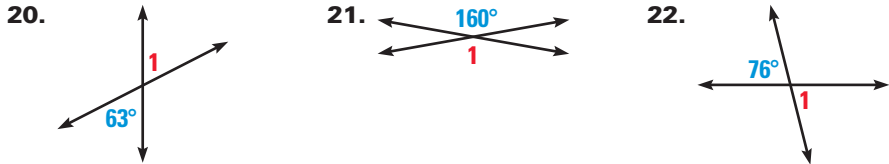
Using the Linear Pair Postulate Find the measure of $\angle 1$.



Linear Pairs Find the measure of the angle described.

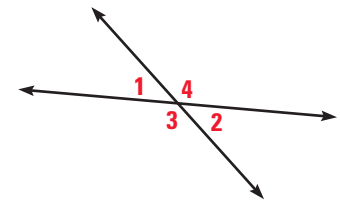
- 18. $\angle 1$ and $\angle 2$ are a linear pair, and $m\angle 1 = 51^\circ$. Find $m\angle 2$.
- 19. $\angle 3$ and $\angle 4$ are a linear pair, and $m\angle 4 = 124^\circ$. Find $m\angle 3$.

Using the Vertical Angles Theorem Find the measure of $\angle 1$.



Evaluating Statements Use the figure below to decide whether the statement is *true* or *false*.

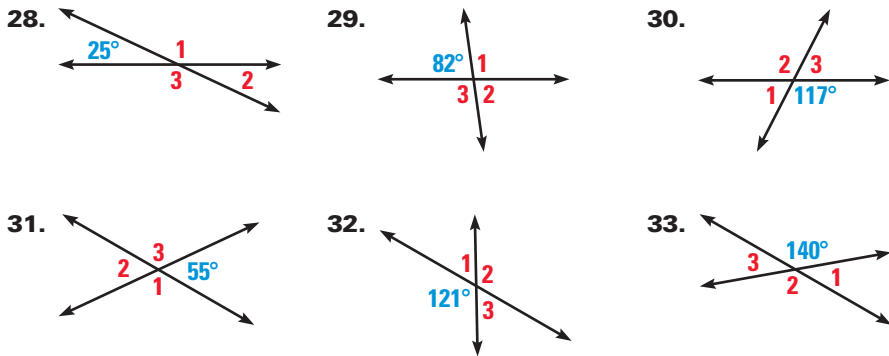
- 23. If $m\angle 1 = 40^\circ$, then $m\angle 2 = 140^\circ$.
- 24. If $m\angle 4 = 130^\circ$, then $m\angle 2 = 50^\circ$.
- 25. $\angle 1$ and $\angle 4$ are a linear pair.
- 26. $m\angle 1 + m\angle 4 = m\angle 3 + m\angle 2$
- 27. $\angle 1$ and $\angle 4$ are vertical angles.



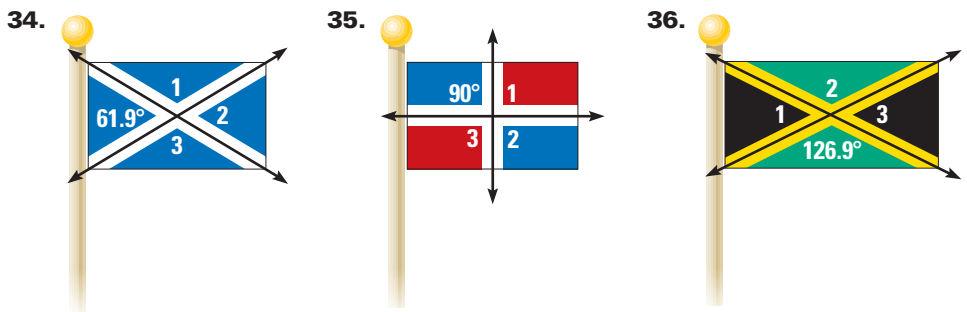
HOMEWORK HELP

Extra help with problem solving in Exs. 28–33 is at classzone.com

Finding Angle Measures Find $m\angle 1$, $m\angle 2$, and $m\angle 3$.



Flags Each flag shown contains vertical angles. Find $m\angle 1$, $m\angle 2$, and $m\angle 3$.



Scotland

Dominican Republic

Jamaica

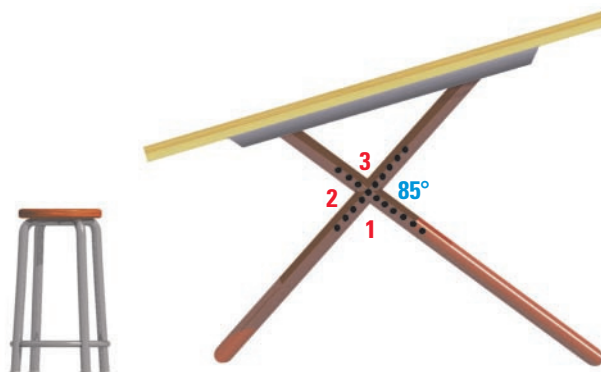
Link to Careers



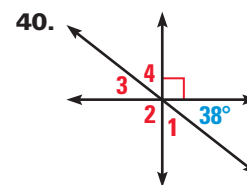
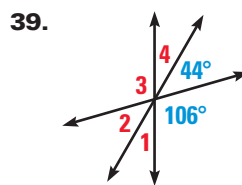
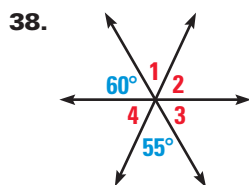
ERGONOMISTS study work conditions to improve the safety, efficiency, and comfort of workers. Drafting tables are angled so people can work at them without injuring their backs.



37. Drafting Table The legs of the drafting table form vertical angles. Find the measures of $\angle 1$, $\angle 2$, and $\angle 3$.

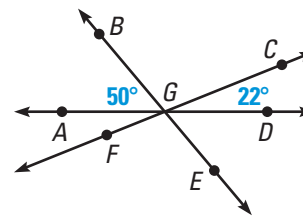


Finding Angle Measures Find $m\angle 1$, $m\angle 2$, $m\angle 3$, and $m\angle 4$.

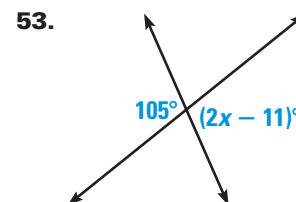
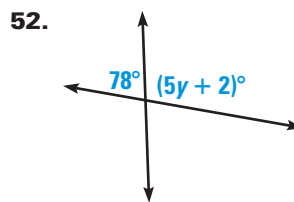
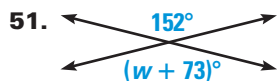


Vertical Angles Use the diagram to complete the statement.

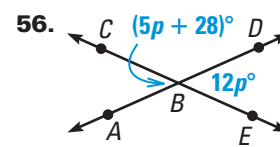
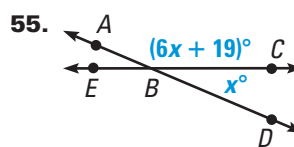
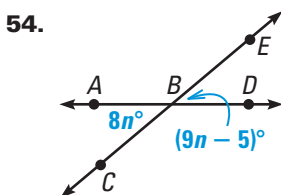
- 41. $\angle BGC \cong \underline{\quad ? \quad}$
- 42. $\angle AGB \cong \underline{\quad ? \quad}$
- 43. $\angle AGC \cong \underline{\quad ? \quad}$
- 44. $\angle CGE \cong \underline{\quad ? \quad}$
- 45. $m\angle AGF = \underline{\quad ? \quad}^\circ$
- 46. $m\angle DGE = \underline{\quad ? \quad}^\circ$
- 47. $m\angle CGE = \underline{\quad ? \quad}^\circ$
- 48. $m\angle BGC = \underline{\quad ? \quad}^\circ$
- 49. $m\angle DGF = \underline{\quad ? \quad}^\circ$
- 50. $m\angle AGD = \underline{\quad ? \quad}^\circ$



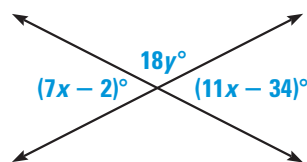
xy Using Algebra Find the value of the variable.



xy Using Algebra Find the value of the variable. Then use substitution to find $m\angle ABC$.



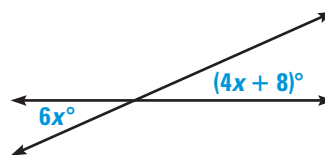
57. **Challenge** Find the values of x and y in the diagram below.



58. **Visualize It!** Sketch and label four angles so that $\angle 1$ and $\angle 2$ are acute vertical angles, $\angle 3$ is a right angle adjacent to $\angle 2$, and $\angle 1$ and $\angle 4$ form a linear pair.

Standardized Test Practice

59. **Multi-Step Problem** Use the diagram below.



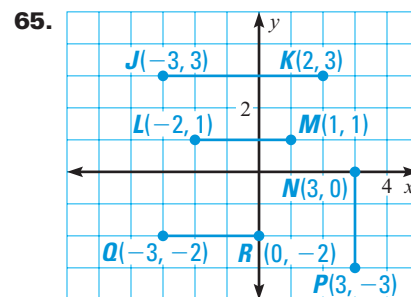
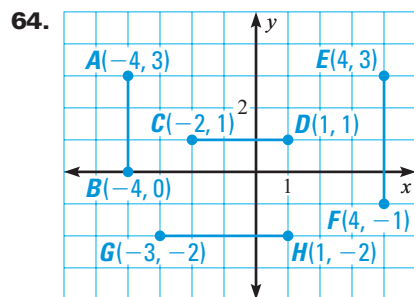
- Use the Vertical Angles Theorem to write an equation.
- Solve your equation to find the value of x .
- Find the measures of the acute angles formed by the lines.
- Find the measures of the obtuse angles formed by the lines.

Mixed Review

Describing Number Patterns Describe a pattern in the numbers. Write the next number you expect in the pattern. (Lesson 1.1)

60. 4, 11, 18, 25, ... 61. 3, 15, 75, 375, ...
 62. 32, 16, 8, 4, ... 63. 404, 414, 424, 434, ...

Congruent Segments Determine which segments in the coordinate plane are congruent. (Lesson 1.5)



Algebra Skills

Simplifying Expressions Simplify the expression. (Skills Review, p. 671)

66. $-16x + 9x$ 67. $7 + a - 2a$ 68. $-8z^2 + 5z^2 - 4$
 69. $6b^2 + 6b - b^2$ 70. $-4(t - 3) - 4t$ 71. $3w^2 - 1 - w^2 + 5$