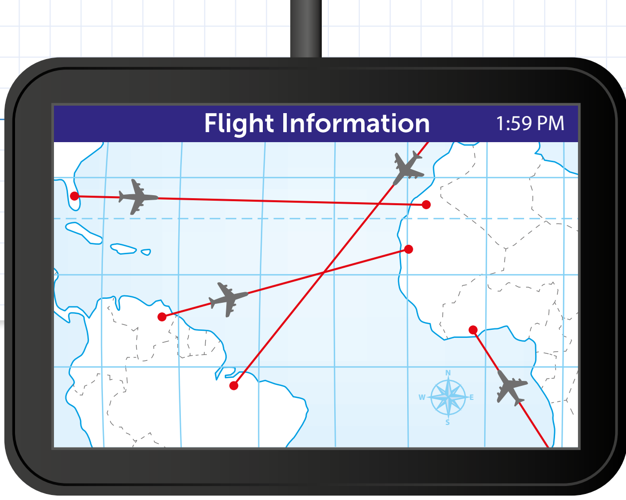
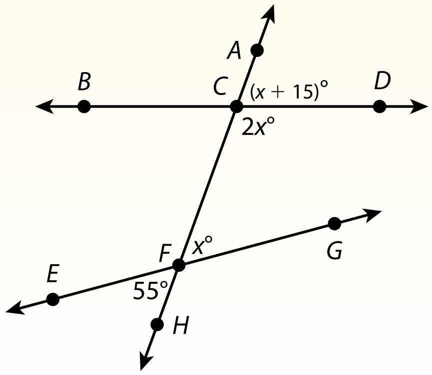
Explore Angle Relationships



Previously, you learned about pairs of angles formed when two lines intersect. In this lesson, you will learn about pairs of angles formed when one line intersects two other lines.

➤ **Use what you know to try to solve the problem below.**

Zahara says she can use angle relationships to find all the angle measures in the figure. What is $m\angle BCF$?



TRY IT

DISCUSS IT

Ask: How did you decide which angle measure to find first?

Share: The first angle measure I found was . . .

Learning Target SMP 1, SMP 2, SMP 3, SMP 4, SMP 5, SMP 6

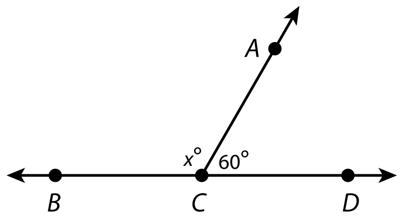
Use informal arguments to establish facts about the angle sum and exterior angle of triangles, about the angles created when parallel lines are cut by a transversal, and the angle-angle criterion for similarity of triangles.

CONNECT IT

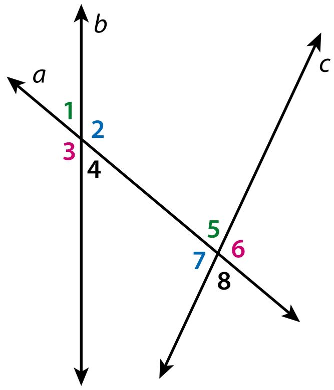
1 **Look Back** What is $m\angle BCF$? What types of angle relationships did you use to find $m\angle BCF$?

2 **Look Ahead** The figure in the **Try It** problem shows pairs of angles you know, such as adjacent angles, supplementary angles, and vertical angles. The figure also shows pairs of angles that are new to you.

a. You know that supplementary angles are two angles whose measures have a sum of 180°. A **linear pair** is a pair of supplementary angles that are adjacent. What two angles form the linear pair shown? What is the value of x?



b. A **transversal** is a line that intersects or cuts two or more lines. Which line is the transversal in the figure at the right?



c. In the figure, $\angle 2$ and $\angle 7$ are **alternate interior angles**. These angles are on opposite sides of the transversal, and they are inside, or between, the other two lines. What is the other pair of alternate interior angles?

d. $\angle 3$ and $\angle 6$ are **alternate exterior angles**. These angles are on opposite sides of the transversal, but are on the outside of the other two lines. What is the other pair of alternate exterior angles?

e. $\angle 1$ and $\angle 5$ are **corresponding angles**. These angles are in the same position relative to the lines and the transversal. $\angle 2$ and $\angle 6$ are also corresponding angles. What are the other two pairs of corresponding angles?

3 **Reflect** Is it possible for a pair of angles to be both corresponding angles and alternate interior angles? Explain.

Name:

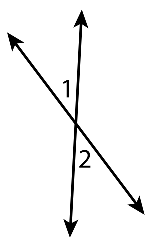
Prepare for Describing Angle Relationships

1 Think about what you know about angles. Fill in each box. Use words, numbers, and pictures. Show as many ideas as you can.

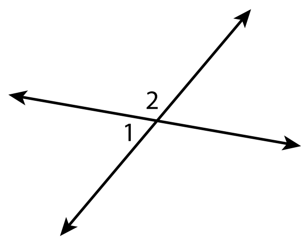
Word	In My Own Words	Example
adjacent angles		
supplementary angles		
vertical angles		

2 For each figure, are ∠1 and ∠2 *adjacent angles* or *vertical angles*? Explain.

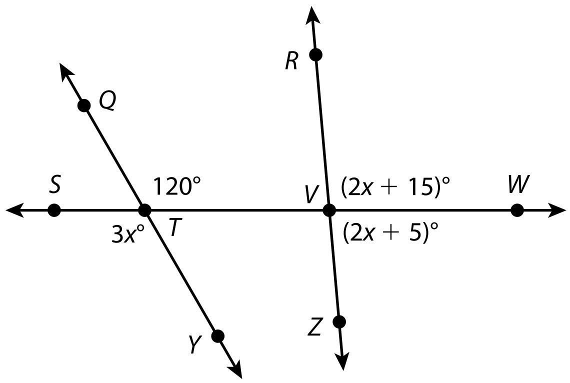
a.



b.



3 **a.** What is $m\angle TVZ$? Show your work.



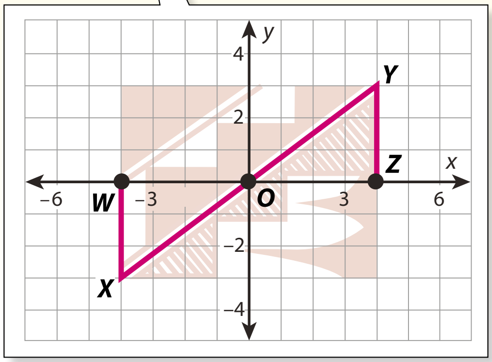
SOLUTION ______________________________

b. Check your answer to problem 3a. Show your work.

Develop Describing Congruent Angle Relationships

➤ **Read and try to solve the problem below.**

The design on this Native American wedding vase contains many angles. Part of the design is shown in the coordinate plane to help show that some angles are congruent. What sequence of transformations can be used to show that $\angle WXO$ and $\angle ZYO$ are congruent?



TRY IT

Math Toolkit graph paper, tracing paper, transparencies

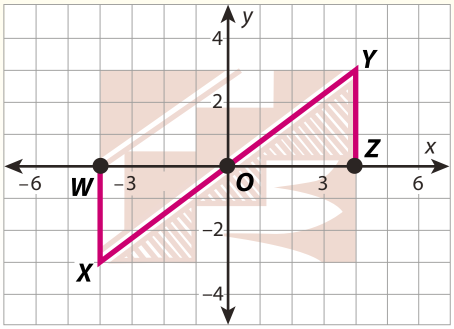
DISCUSS IT

Ask: How did you choose which transformation to use?

Share: I noticed that . . .

➤ Explore different ways to find and describe congruent angle relationships.

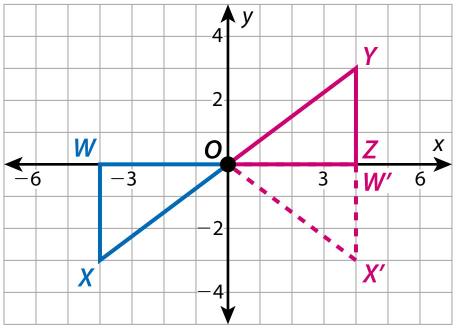
The design on this Native American wedding vase contains many angles. Part of the design is shown in the coordinate plane to help show that some angles are congruent. What sequence of transformations can be used to show that ∠*WXO* and ∠*ZYO* are congruent?



Model It

You can use reflections.

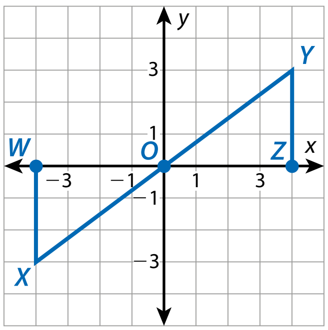
A sequence of two reflections maps ∠*WXO* onto ∠*ZYO*.

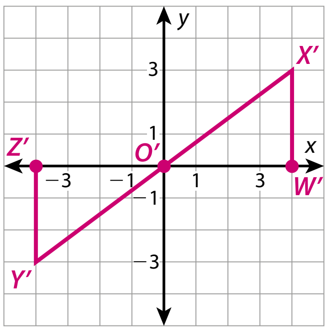


Model It

You can use a rotation.

Rotate the entire figure 180° around the origin to map ∠*WXO* onto ∠*W′X′O′*.



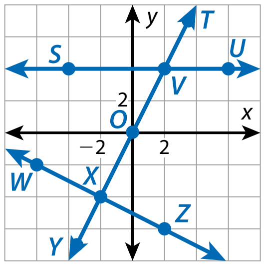


CONNECT IT

➤ **Use the problem from the previous page to help you understand how to find and describe congruent angle relationships.**

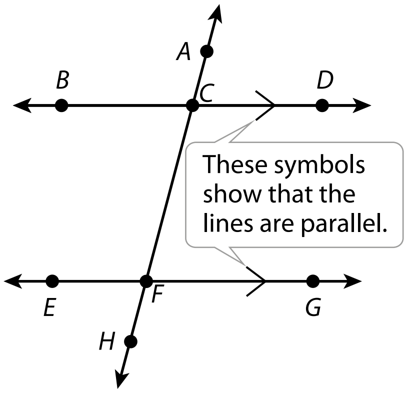
1. $\angle WXO$ and $\angle ZYO$ in the **Try It** problem are alternate interior angles. How can you tell? How do you know these angles are congruent?

2. Can you use a sequence of transformations to show that the pairs of alternate interior angles in this figure are congruent? Explain.



3. **a.** Alternate interior angles formed by parallel lines cut by a transversal are congruent. Mark the two pairs of alternate interior angles that are congruent. Then mark the vertical angles that are congruent.

   b. Name the pairs of alternate exterior angles in the figure. How are alternate exterior angles related when formed by parallel lines cut by a transversal?



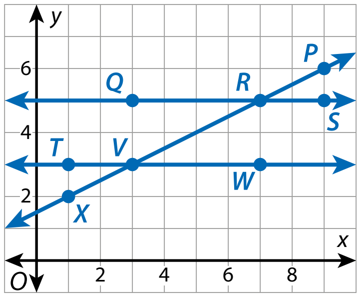
   c. Name the pairs of corresponding angles in the figure. How are corresponding angles related when formed by parallel lines cut by a transversal?

4. **Reflect** Think about all the models and strategies you have discussed today. Describe how one of them helped you better understand the congruent angles formed by parallel lines cut by a transversal.

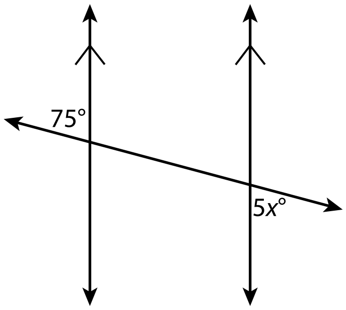
Apply It

Use what you learned to solve these problems.

5 Name a pair of corresponding angles in the figure. What sequence of transformations could you use to show that the angles are congruent?

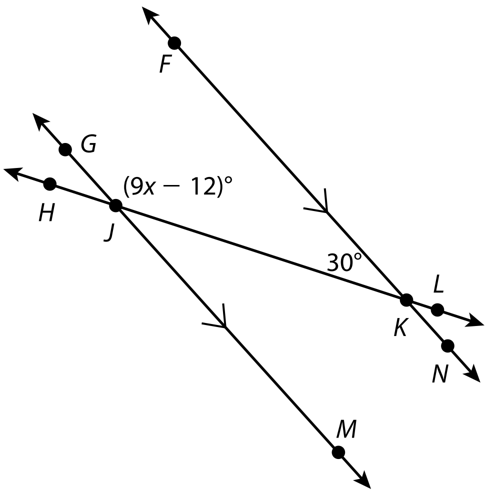


6 Find the value of x. Show your work.



SOLUTION ______________________________

7 Find the value of x. Show your work.



SOLUTION ______________________________

Practice Describing Congruent Angle Relationships

➤ **Study the Example showing how to use angle relationships to find unknown angle measures. Then solve problems 1–6.**

Example

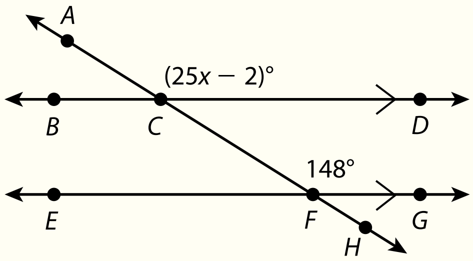
What is the value of *x*?

$\overline{BD}$ and $\overline{EG}$ are parallel, so corresponding angles are congruent.

$25x - 2 = 148$

$25x = 150$

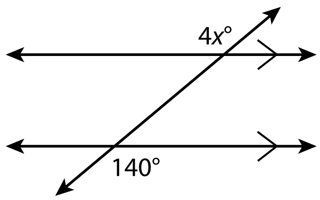
$x = 6$



1 **a.** In the Example, what angle forms a pair of alternate interior angles with $\angle CFG$?

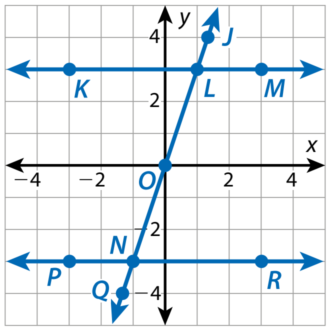
b. What is the measure of the angle you named in problem 1a?

2 What is the value of *x*? Show your work.



SOLUTION ______________________________

3 Describe a sequence of transformations you can use to show $\angle JLK \cong \angle QNR$.



Vocabulary

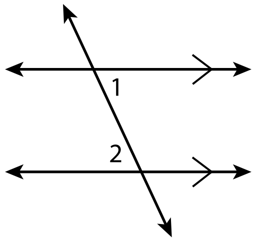
alternate exterior angles
when two lines are cut by a transversal, a pair of angles on opposite sides of the transversal and outside the two lines.

alternate interior angles
when two lines are cut by a transversal, a pair of angles on opposite sides of the transversal and between the two lines.

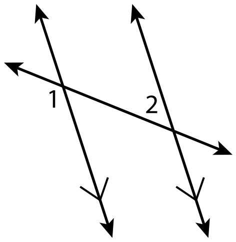
corresponding angles
angles in the same relative position when two lines are cut by a transversal.

4 In which figures is $\angle 1 \cong \angle 2$? Select all that apply.

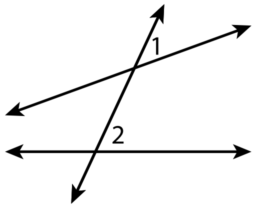
A



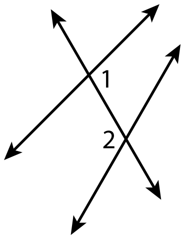
B



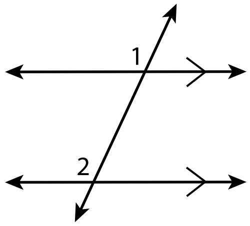
C



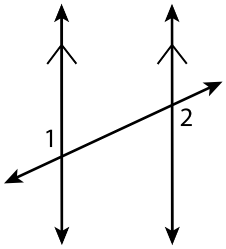
D



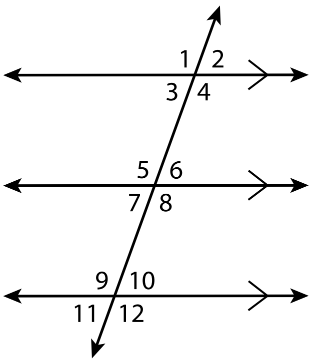
E



F

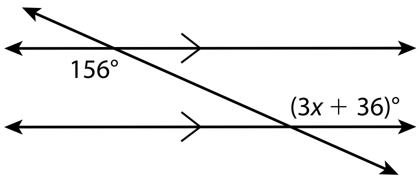


5 Tell whether each statement about the figure is *True* or *False*.



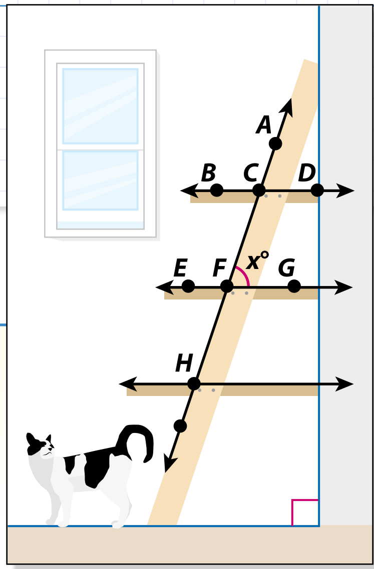
	True	**False**
a. $\angle 1$ and $\angle 9$ are corresponding angles.	◯	◯
b. $\angle 2$ and $\angle 7$ are alternate exterior angles.	◯	◯
c. $\angle 3$ and $\angle 10$ are alternate interior angles.	◯	◯
d. $\angle 4$ and $\angle 7$ are alternate interior angles.	◯	◯

6 What is the value of x? Show your work.



SOLUTION ____________________

Develop Describing Supplementary Angle Relationships



Read and try to solve the problem below.

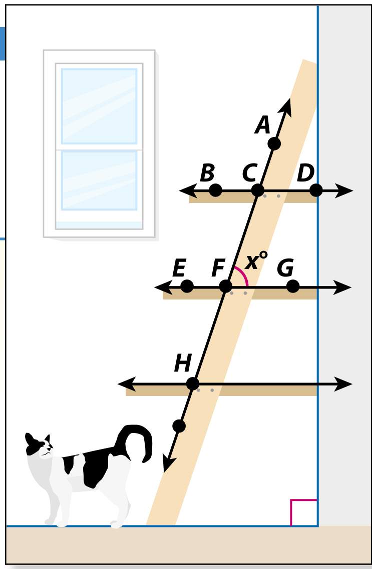
A ladder shelf is a shelf that leans against a wall like a ladder. The image shows a side view of a ladder shelf. There are three parallel shelves supported by a brace. The brace acts like a transversal. Write an expression for $m\angle DCF$ in terms of x.

TRY IT

DISCUSS IT

Ask: Why did you choose that strategy to find an expression for $m\angle DCF$?

Share: I knew . . . so I . . .



➤ **Explore different ways to find and describe supplementary angle relationships.**

A ladder shelf is a shelf that leans against a wall like a ladder. The image shows a side view of a ladder shelf. There are three parallel shelves supported by a brace. The brace acts like a transversal. Write an expression for $m\angle DCF$ in terms of x.

Model It

You can use what you know about alternate interior angles.

$\overleftrightarrow{BD} \parallel \overleftrightarrow{EG}$, so $\angle EFC$ and $\angle DCF$ are congruent alternate interior angles.

$\angle EFC$ and $\angle CFG$ form a linear pair, so $m\angle EFC + m\angle CFG = 180°$.

$m\angle EFC = m\angle DCF$, so you can substitute $m\angle DCF$ for $m\angle EFC$:

$m\angle DCF + m\angle CFG = 180°$

Model It

You can use what you know about corresponding angles.

$\overleftrightarrow{BD} \parallel \overleftrightarrow{EG}$, so $\angle ACD$ and $\angle CFG$ are congruent corresponding angles.

$\angle ACD$ and $\angle DCF$ form a linear pair, so $m\angle ACD + m\angle DCF = 180°$.

$m\angle ACD = m\angle CFG$, so you can substitute $m\angle CFG$ for $m\angle ACD$:

$m\angle CFG + m\angle DCF = 180°$

CONNECT IT

➤ **Use the problem from the previous page to help you understand how to find and describe supplementary angle relationships.**

1 Look at both **Model Its**. What is $m\angle CFG$? What is an expression for $m\angle DCF$ in terms of x?

2 Would this relationship be true if the lines cut by the transversal were not parallel? Explain.

3 **a.** In **Try It**, $\angle DCF$ and $\angle CFG$ are **same-side interior angles**. These angles are on the same side of the transversal, between $\overleftrightarrow{BD}$ and $\overleftrightarrow{EG}$. How are the measures of same-side interior angles related when when they are formed by parallel lines cut by a transversal?

b. In **Try It**, $\angle ACD$ and $\angle HFG$ are **same-side exterior angles**. These angles are on the same side of the transversal, not between $\overleftrightarrow{BD}$ and $\overleftrightarrow{EG}$. How are their measures related? Explain.

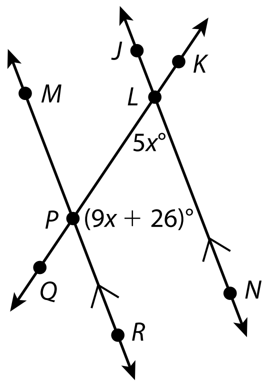
4 You can use the angles formed by two lines cut by a transversal to conclude that the two lines are parallel. For example, the lines are parallel if corresponding angles are congruent. Use similar reasoning to explain how to show two lines are parallel using same-side interior or same-side exterior angles.

5 **Reflect** Think about all the models and strategies you have discussed today. Describe how one of them helped you better understand the supplementary angles formed by parallel lines and angle relationships.

Apply It

➤ **Use what you learned to solve these problems.**

6 What is $m\angle LPR$? Show your work.



SOLUTION ____

7 Which of these situations show that the lines cut by a transversal are parallel? Select all that apply.

A alternate exterior angles are supplementary

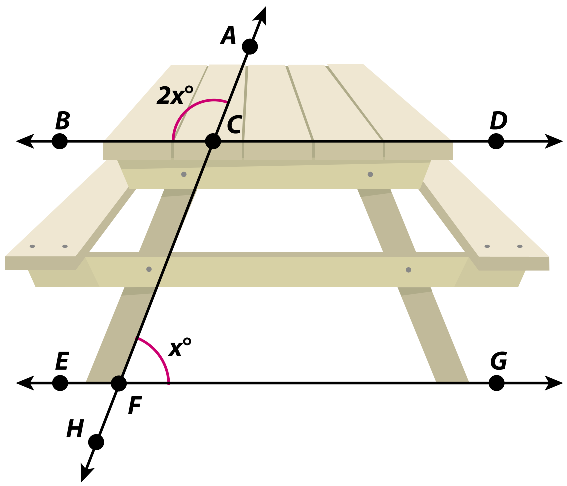
B alternate interior angles are supplementary

C corresponding angles are congruent

D same-side exterior angles are congruent

E same-side interior angles are supplementary

8 The figure shows a picnic table. The top is represented by $\overleftrightarrow{BD}$. The ground is represented by $\overleftrightarrow{EG}$. The table leg represented by $\overleftrightarrow{AH}$ acts like a transversal. What value of x will show that the table top is parallel to the ground? Show your work.



SOLUTION ____

Name:

Practice Describing Supplementary Angle Relationships

➤ **Study the Example showing how to use angle relationships to solve problems. Then solve problems 1–5.**

Example

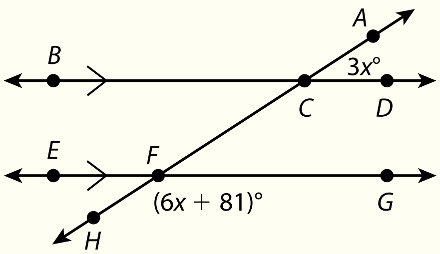
What is the value of x?

$\angle ACD$ and $\angle HFG$ are same-side exterior angles. $\overleftrightarrow{BD}$ and $\overleftrightarrow{EG}$ are parallel, so $m\angle ACD + m\angle HFG = 180°$.

$3x + 6x + 81 = 180$

$9x = 99$

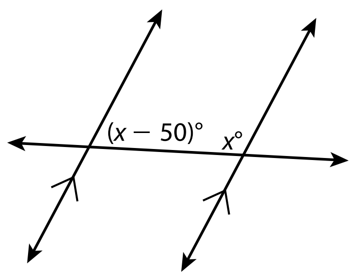
$x = 11$



1 What is the angle relationship between $\angle DCF$ and $\angle CFG$ in the Example? What are the measures of these angles? Show your work.

SOLUTION ______________________________

2 Find the value of x. Show your work.



SOLUTION ______________________________

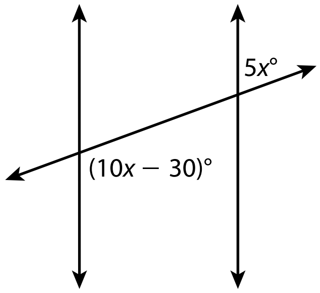
Vocabulary

same-side exterior angles
when two lines are cut by a transversal, a pair of angles on the same side of the transversal and outside the two lines.

same-side interior angles
when two lines are cut by a transversal, a pair of angles on the same side of the transversal and between the two lines.

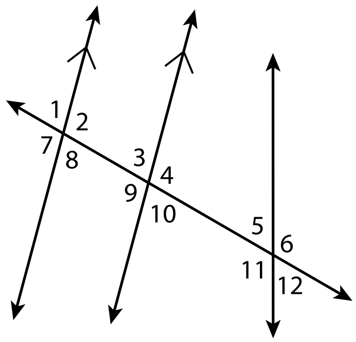
transversal
a line that cuts two or more lines.

3 The figure shows two lines cut by a transversal. What value of x shows that the lines are parallel? Show your work.



SOLUTION ______________________________

4 Which statements about the figure are true? Select all that apply.



A $\angle 2 \cong \angle 3$

B $\angle 10$ and $\angle 11$ are supplementary angles.

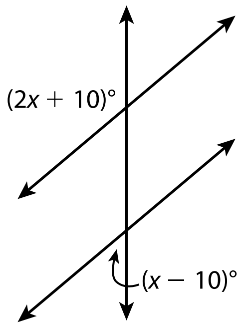
C $\angle 2$ are $\angle 5$ are same-side interior angles.

D $\angle 8$ and $\angle 9$ are supplementary angles.

E $\angle 9$ and $\angle 12$ are same-side exterior angles.

F $m\angle 3 + m\angle 6 = 180°$

5 The figure shows two lines cut by a transversal. What value of x shows that the lines parallel? Show your work.



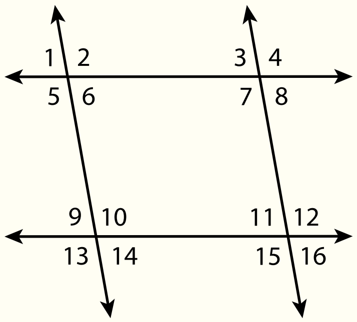
SOLUTION ______________________________

Refine Describing Angle Relationships

➤ **Complete the Example below. Then solve problems 1–10.**

Example

The figure shows a pair of parallel lines intersected by another pair of parallel lines. How are the measures of ∠6 and ∠12 related?



Look at how you could use angle relationships.

$\angle 6 \cong \angle 8$ ⟵ Corresponding angles are congruent.

$m\angle 8 + m\angle 12 = 180°$ ⟵ Same-side interior angles are supplementary.

$m\angle 6 + m\angle 12 = 180°$ ⟵ Substitute $m\angle 6$ for $m\angle 8$.

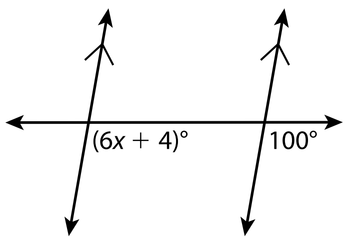
SOLUTION ______________________________

CONSIDER THIS . . .
Each line in the figure is also a transversal.

PAIR/SHARE
What is another way to solve the problem?

Apply It

1 What is the value of x? Show your work.



SOLUTION ______________________________

CONSIDER THIS . . .
How are the labeled angles related?

PAIR/SHARE
Explain how to check if your answer is reasonable.

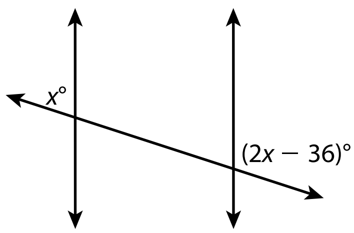
2 Draw the lines described. Then label any angle measures that you can determine.

Two parallel lines are cut by a transversal. The alternate interior angles are supplementary.

CONSIDER THIS . . .
How are alternate interior angles related when formed by parallel lines cut by a transversal?

PAIR/SHARE
Suppose the alternate interior angles were congruent instead of supplementary. What angle measures can you calculate now?

3 The figure shows two lines cut by a transversal. Which value of x shows that the lines are parallel?



A $x = 36$

B $x = 42$

C $x = 48$

D $x = 72$

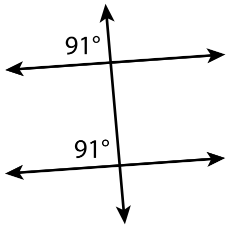
Noah chose A as the correct answer. How might he have gotten that answer?

CONSIDER THIS . . .
What needs to be true about the angles labeled for the lines to be parallel?

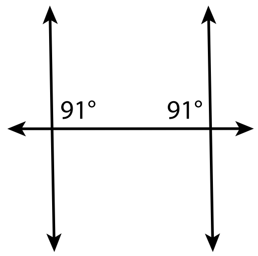
PAIR/SHARE
If the lines are parallel, what are the measures of the eight angles formed where the transversal crosses?

4 Which figures show parallel lines? Select all that apply.

A



B



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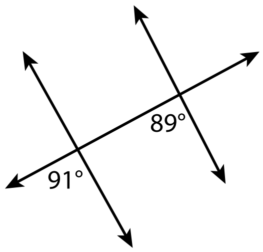

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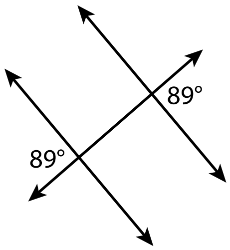

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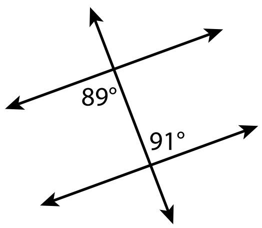

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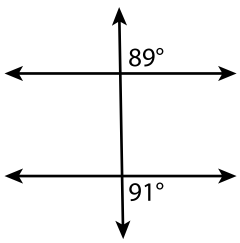
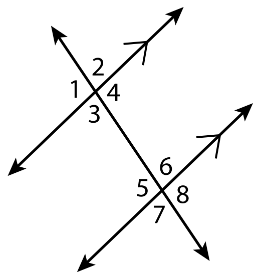
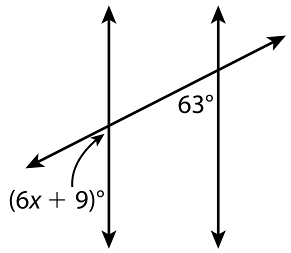


5 Which angles are congruent to $\angle 5$? How do you know?

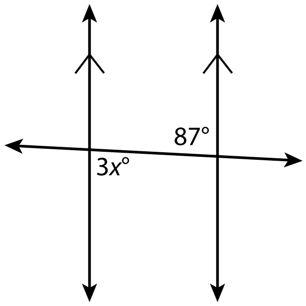


6 The figure shows two lines cut by a transversal. Are the lines parallel if $x = 9$? Explain.



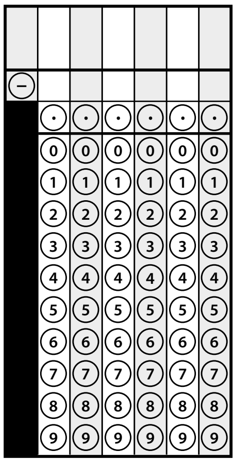
7 Two lines cut by a transversal are parallel if the alternate exterior angles formed are ______________ .

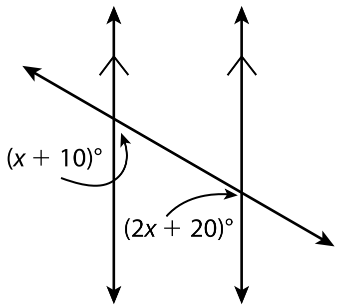
8 What is the value of x? Show your work.



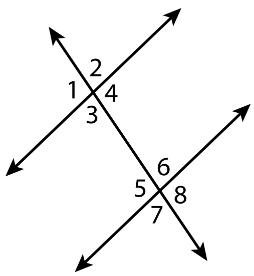
SOLUTION ____

9 What is the value of x?



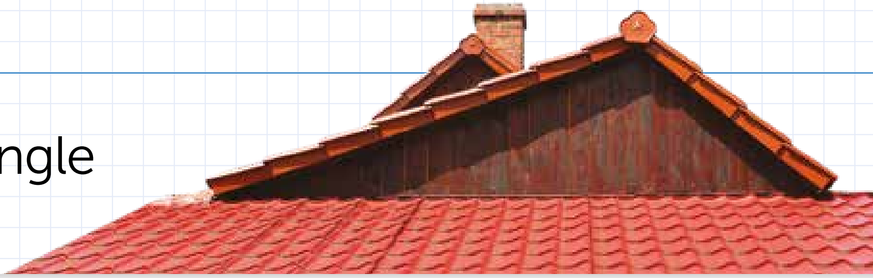


10 **Math Journal** In the figure, $\angle 3 \cong \angle 6$. Explain how you know that all four pairs of corresponding angles are congruent.



End of Lesson Checklist

- ☐ **INTERACTIVE GLOSSARY** Find the entries for *corresponding angles, alternate interior angles,* and *same-side interior angles.* Sketch an example for each term.
- ☐ **SELF CHECK** Go back to the Unit 2 Opener and see what you can check off.

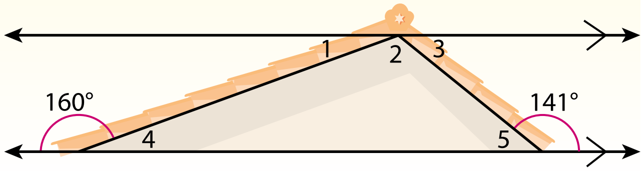


Explore The Sum of the Angle Measures in a Triangle

Previously, you learned about the measures of angles formed by parallel lines and transversals. In this lesson, you will learn about angle measures of triangles.

Use what you know to try to solve the problem below.

An architect needs to know the angle measures of the roof shown in the photo. The triangle to the right models the shape of the roof. What is the sum of the angle measures of the triangle?



TRY IT

Math Toolkit grid paper, straightedges

DISCUSS IT

Ask: What did you do first to find the sum of the angle measures?

Share: First, I found the angle measures by . . .

Learning Target SMP 1, SMP 2, SMP 3, SMP 4, SMP 5, SMP 6

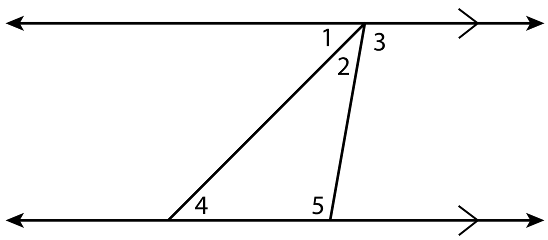
Use informal arguments to establish facts about the angle sum and exterior angle of triangles, about the angles created when parallel lines are cut by a transversal, and the angle-angle criterion for similarity of triangles.

CONNECT IT

1 **Look Back** Write an equation to show the sum of the angle measures of the triangle in the **Try It**.

2 **Look Ahead** You know several angle relationships related to parallel lines being cut by a transversal. You can use these relationships to find the sum of the angle measures of a triangle.

a. Look at this figure. How do you know that $m\angle 1 = m\angle 4$ and $m\angle 3 = m\angle 5$?



b. Write an equation for the sum of the measures of $\angle 1$, $\angle 2$, and $\angle 3$. How do you know the sum of these angle measures?

c. Use your answers to problems 2a and 2b to find the sum of the measures of the angles of the triangle, $m\angle 2 + m\angle 4 + m\angle 5$.

3 **Reflect** Is the sum you found in problem 2c the same as the sum you found in the **Try It**? Do you think you would get this result for any triangle? Explain.

Name:

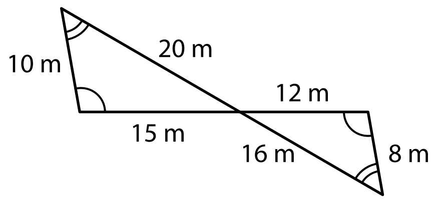
Prepare for Angle Relationships in Triangles

1 Think about what you know about similarity and similar triangles. Fill in each box. Use words, numbers, and pictures. Show as many ideas as you can.

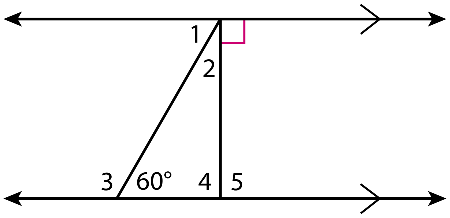
similar triangles

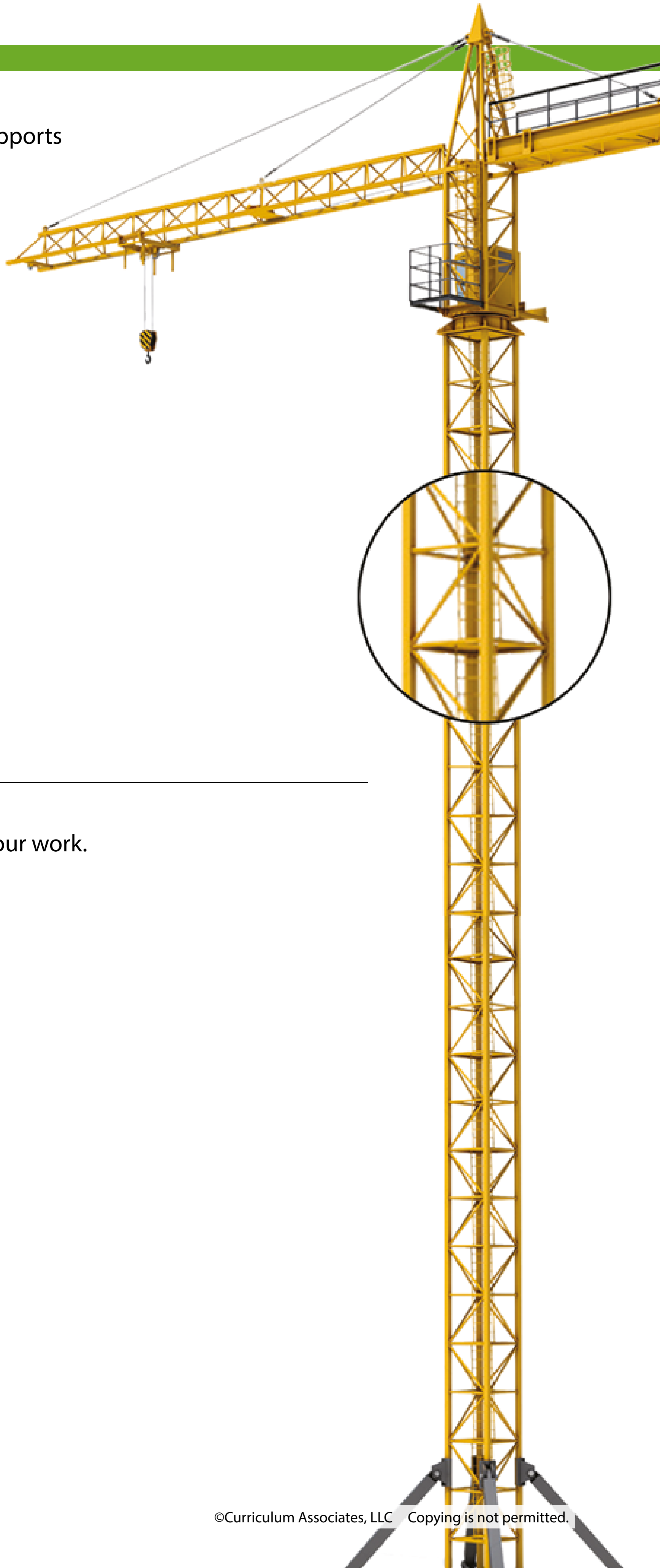
In My Own Words	**My Illustrations**
Examples	**Non-Examples**

2 Are the triangles similar? Explain.



3 The triangle below models a section of the supports you might see in a construction crane.



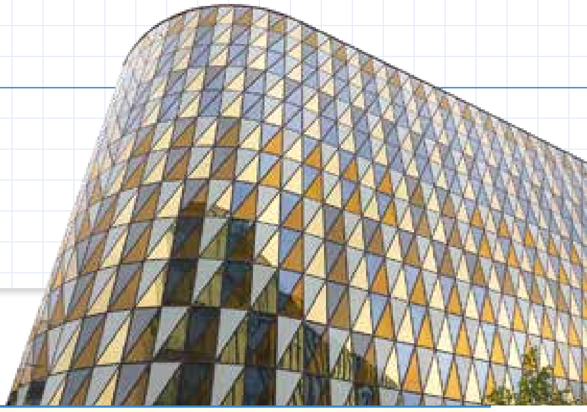


a. What is the sum of the angle measures of the triangle? Show your work.

SOLUTION ______________________________

b. Check your answer to problem 3a. Show your work.

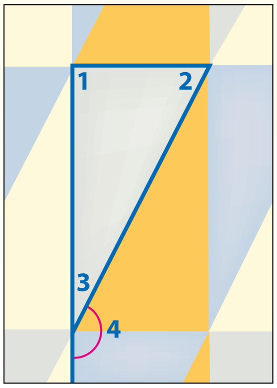
Develop Describing the Exterior Angles of a Triangle



➤ **Read and try to solve the problem below.**

The triangular windows of the Aula Medica conference center in Sweden are formed by three sets of parallel lines going in different directions.

A close-up of the window design shows a triangle. The measure of $\angle 4$ is related to the angle measures of the triangle. How can you use the measures of $\angle 1$ and $\angle 2$ to write an expression for the measure of $\angle 4$?



TRY IT

DISCUSS IT

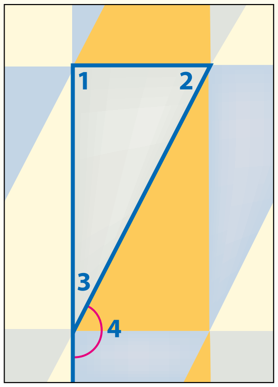
Ask: What steps did you take to find the expression?

Share: I began by . . .

Explore different ways to describe angle relationships in triangles.

The triangular windows of the Aula Medica conference center in Sweden are formed by three sets of parallel lines going in different directions.

A close-up of the window design shows a triangle. The measure of $\angle 4$ is related to the angle measures of the triangle. How can you use the measures of $\angle 1$ and $\angle 2$ to write an expression for the measure of $\angle 4$?



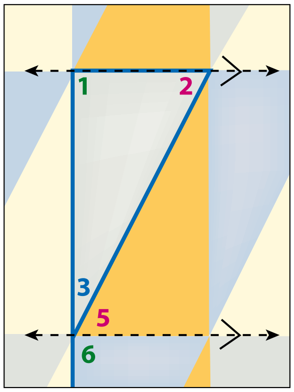
Picture It

You can look for pairs of congruent angles.

$m\angle 4 = m\angle 5 + m\angle 6$

$m\angle 5 = m\angle 2$ ⟵ $\angle 2$ and $\angle 5$ are alternate interior angles.

$m\angle 6 = m\angle 1$ ⟵ $\angle 1$ and $\angle 6$ are corresponding angles.



Model It

You can use angle relationships.

$m\angle 1 + m\angle 2 + m\angle 3 = 180°$ ⟵ The sum of the angle measures of a triangle is 180°.

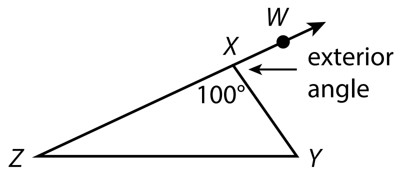
$m\angle 3 + m\angle 4 = 180°$ ⟵ $\angle 3$ and $\angle 4$ form a linear pair.

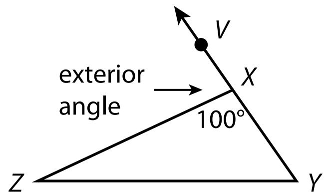
$m\angle 1 + m\angle 2 + m\angle 3 = m\angle 3 + m\angle 4$

CONNECT IT

➤ **Use the problem from the previous page to help you understand angle relationships in triangles.**

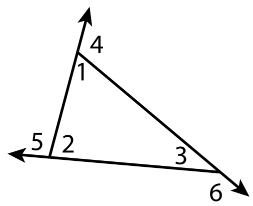
1. An **exterior angle** of a triangle is formed by extending one side of a triangle. There are two exterior angles at each vertex of a triangle, as shown for $\angle ZXY$ in the figures at the right. Why are the two exterior angles at the same vertex congruent?





2. Look at **Model It**. Simplify the last equation. What is the relationship between an exterior angle of a triangle and its nonadjacent interior angles?

3. Look at the triangle to the right. Use the measures of the interior angles to write an equation for the measure of each exterior angle.



4. Use the equations you wrote in problem 3 to find the sum of the measures of the exterior angles of a triangle, one at each vertex.

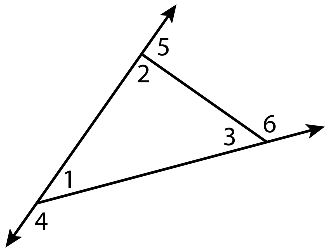
5. Do you think your answers to problems 2 and 4 are true for all triangles? Explain.

6. **Reflect** Think about all the models and strategies you have discussed today. Describe how one of them helped you better understand how to solve the **Try It** problem.

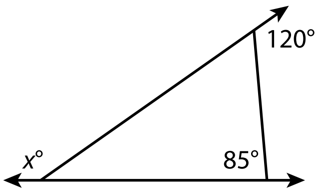
Apply It

➤ **Use what you learned to solve these problems.**

7 Use linear pairs to find the sum of all the angles labeled in the triangle. Then use what you know about the interior angles of a triangle to show that the sum of the measures of the exterior angles of a triangle, one at each vertex, is 360°.



8 Which equations can you use to find the value of x? Select all that apply.



A $x + 120 + 85 = 180$

B $x + 85 = 120$

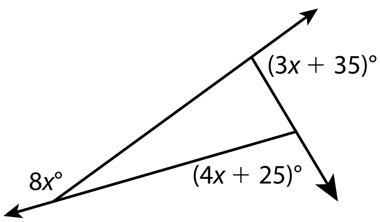
C $x + 120 + 95 = 360$

D $x = 60 + 85$

E $x + 60 + 85 = 180$

F $x + 35 = 180$

9 What is the value of x? Show your work.



SOLUTION ______________________________

Name:

Practice Describing the Exterior Angles of a Triangle

➤ **Study the Example showing how to use the relationship between exterior and interior angles of a triangle. Then solve problems 1–6.**

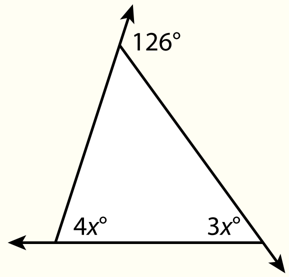
Example

Find the value of *x*.

$$4x + 3x = 126$$

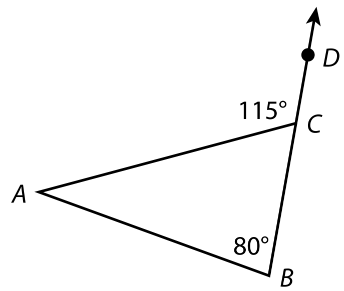
$$7x = 126$$

$$x = 18$$



1 What are the three exterior angle measures of the triangle in the Example?

2 What is $m\angle CAB$? Show your work.



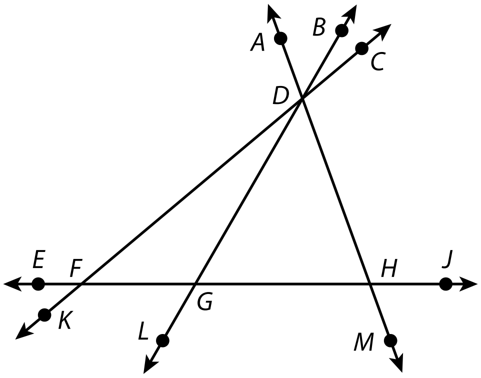
SOLUTION ______________________________

3 Can a triangle have an exterior angle that measures 90° at two different vertices? Explain.

Vocabulary

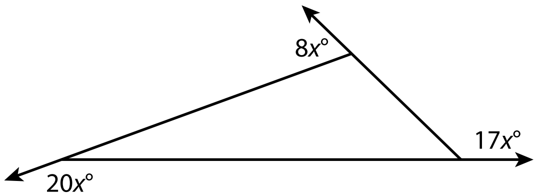
exterior angle
when you extend one side of a polygon, the angle between the extended side and the adjacent side.

4 Tell whether each statement about the diagram is *True* or *False*.



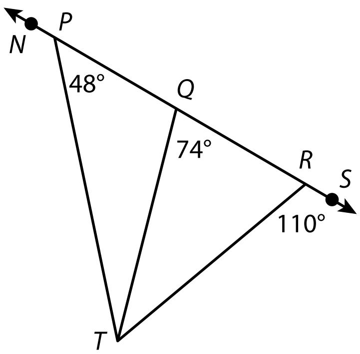
	True	False
a. $\angle FGD$ is an exterior angle of $\triangle DHG$.	◯	◯
b. $m\angle EFD + m\angle HGD = m\angle FDG$	◯	◯
c. $m\angle DFH + m\angle FDH = m\angle GHM$	◯	◯
d. $m\angle GDH + m\angle DHG = m\angle EGL$	◯	◯
e. $m\angle DHJ + m\angle DGE + m\angle BDH = 360°$	◯	◯

5 What is the value of x? Show your work.



SOLUTION ______________________________

6 **a.** What is $m\angle QTR$? Show your work.



SOLUTION ______________________________

b. What is $m\angle PTR$? Show your work.

SOLUTION ______________________________

Develop Using Angles to Determine Similar Triangles

➤ **Read and try to solve the problem below.**

Jorge wants to draw two triangles that have the same angle measures and are not similar. Carlos says that is not possible to do.

Make or draw two triangles that have the same three angle measures but different side lengths. Are the triangles similar?

TRY IT

Math Toolkit grid paper, protractors, rulers

DISCUSS IT

Ask: How did you make sure that the angles of your triangles had the same measures?

Share: After I made the first triangle . . .

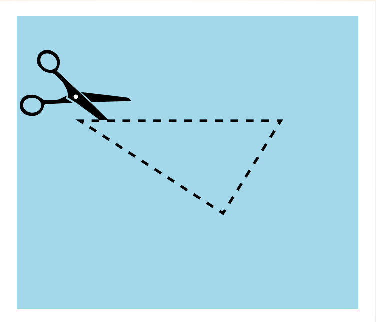
➤ **Explore different ways to make triangles with the same angle measures.**

Jorge wants to draw two triangles that have the same angle measures and are not similar. Carlos says that is not possible to do.

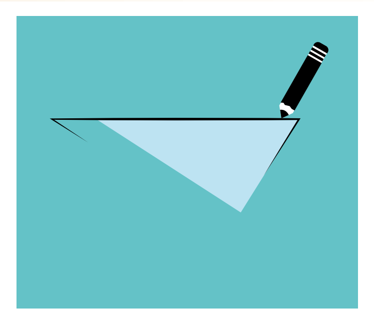
Make or draw two triangles that have the same three angle measures but different side lengths. Are the triangles similar?

Model It

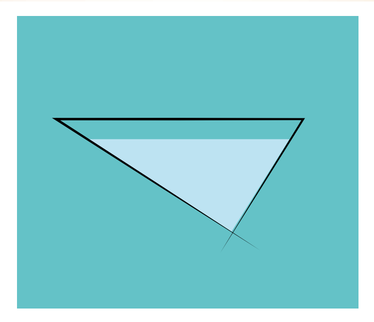
You can cut out a triangle and trace its angles to make a second triangle.



Draw one side of the second triangle so that it is longer than a side of the first triangle. Trace two angles of the first triangle at either end of the new side.



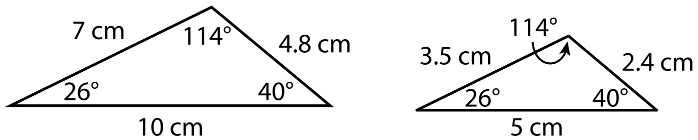
Extend the two sides to complete the triangle. Be sure the third angle matches the third angle of the first triangle.



Model It

You can choose angle measures and one pair of corresponding side lengths.

For example, draw triangles with angles of 26°, 40°, and 114° such that there is one pair of corresponding sides with lengths 10 cm and 5 cm. Measure and compare the other corresponding side lengths.



CONNECT IT

➤ **Use the problem from the previous page to help you understand how to use angle measures to tell whether two triangles are similar.**

1 Look at the pairs of triangles you and your classmates accurately made or drew as you worked on the **Try It** problem. Are the triangles in each pair similar? Explain.

2 Look at the triangles in the second **Model It**. Are the triangles similar? Explain.

3 Will all possible triangles with the same three angle measures be similar? Explain.

4 Suppose two angle measures of one triangle are equal to two angle measures of another triangle. Must the third angle measures also be equal? Explain.

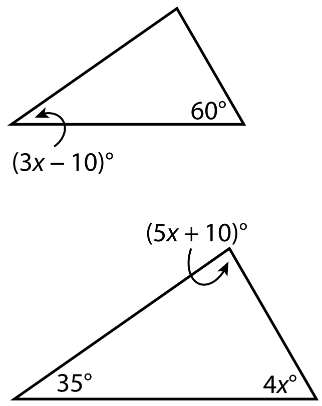
5 Suppose two triangles have two pairs of corresponding angles that are congruent. Are the triangles similar? Explain.

6 **Reflect** Think about all the models and strategies you have discussed today. Describe how one of them helped you better understand how to solve the **Try It** problem.

Apply It

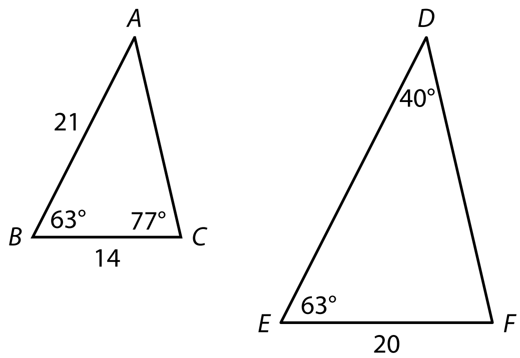
➤ **Use what you learned to solve these problems.**

7 Are the triangles similar? How do you know? Show your work.



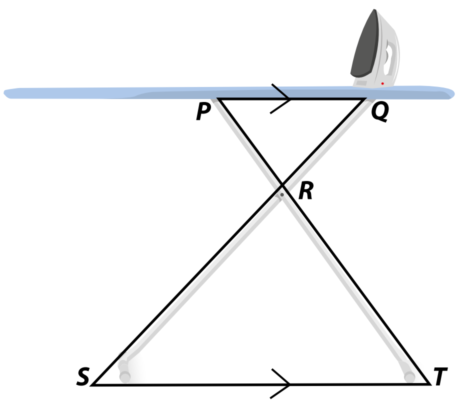
SOLUTION ______________________________

8 Find *DE*. Show your work.



SOLUTION ______________________________

9 An ironing board, its legs, and the floor form two triangles as shown in the figure. The top of the board, $\overline{PQ}$, is parallel to the floor, $\overline{ST}$. Write a similarity statement for the two triangles. Explain how you know that they are similar.



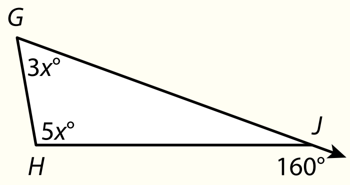
Name:

Practice Using Angles to Determine Similar Triangles

➤ **Study the Example showing how to use angle measures to identify similar triangles. Then solve problems 1–6.**

Example

Which triangles are similar?



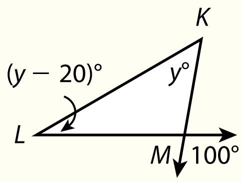
$3x + 5x = 160$

$8x = 160$

$x = 20$

$m\angle HGJ = 60°$, $m\angle GHJ = 100°$

$m\angle GJH = 180° - 160° = 20°$



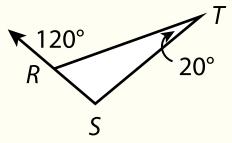
$100 + y + y - 20 = 180$

$2y + 80 = 180$

$2y = 100$

$y = 50$

$m\angle LKM = 50°$, $m\angle KLM = 30°$



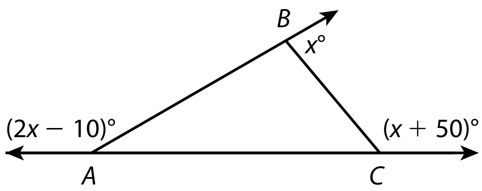
$m\angle SRT = 180° - 120°$

$= 60°$

$m\angle RTS = 20°$

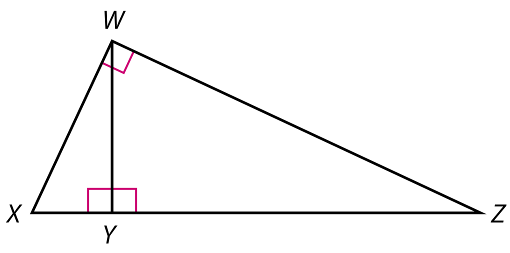
$\angle HGJ \cong \angle SRT$ and $\angle GJH \cong \angle RTS$, so $\triangle GHJ \sim \triangle RST$.

1 Is $\triangle ABC$ similar to any of the triangles in the Example? Explain.



2 Triangle X has two angles that measure 80° and 30°. Triangle Y has two angles that measure 80° and 70°. Hannah says that triangles X and Y are not similar. Jasmine says they are similar. Who is correct? Explain.

3 **a.** Is $\triangle XYW \sim \triangle XWZ$? Explain why or why not.



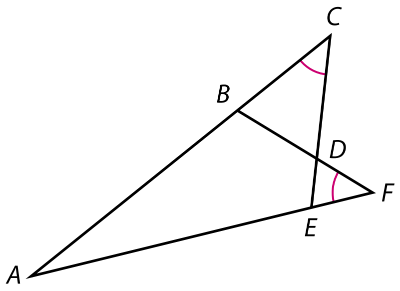
b. Is $\triangle WYZ \sim \triangle XWZ$? Explain why or why not.

c. Is $\triangle XYW \sim \triangle WYZ$? Explain why or why not.

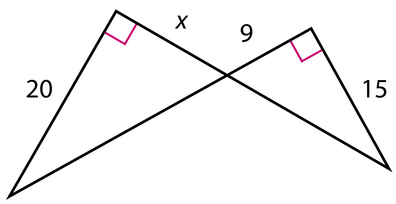
4 In the figure at the right, $\angle C \cong \angle F$.

a. Which triangle is similar to $\triangle BCD$?

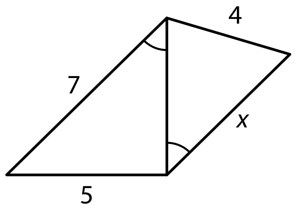
b. Which triangle is similar to $\triangle ACE$?



5 Can you use the information in the figure to show that the triangles are similar? Explain. If so, find the value of x.



6 Can you use the information in the figure to show that the triangles are similar? Explain. If so, find the value of x.



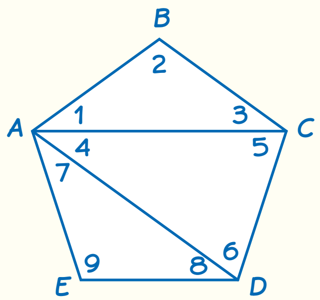
Refine Describing Angle Relationships in Triangles

➤ **Complete the Example below. Then solve problems 1–10.**

Example

What is the sum of the angle measures of a pentagon?

Look at how you could use the sum of the angle measures of a triangle.



$m\angle EAB + m\angle ABC + m\angle BCD + m\angle CDE + m\angle DEA =$

$(m\angle 7 + m\angle 4 + m\angle 1) + m\angle 2 + (m\angle 3 + m\angle 5) +$
$(m\angle 6 + m\angle 8) + m\angle 9 =$

$(m\angle 1 + m\angle 2 + m\angle 3) + (m\angle 4 + m\angle 5 + m\angle 6) +$
$(m\angle 7 + m\angle 8 + m\angle 9) = 180° + 180° + 180°$

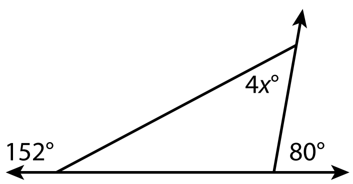
SOLUTION ______________________________

CONSIDER THIS . . . How can you draw triangles so that the angles of the triangles make up the angles of the pentagon?

PAIR/SHARE Can you use the same strategy to find the sum of the angle measures of a hexagon? Explain.

Apply It

1 What is the value of *x*? Show your work.

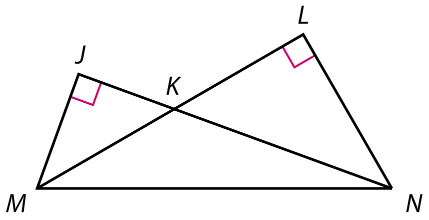


SOLUTION ______________________________

CONSIDER THIS . . . How is each exterior angle measure related to the interior angle measures?

PAIR/SHARE How could you use a different angle relationship to solve this problem?

2 Explain how you know that $\triangle MJK \sim \triangle NLK$.



CONSIDER THIS . . .
Look at each pair of corresponding angles.

PAIR/SHARE
Is $\triangle MJN \sim \triangle NLM$? How do you know?

3 A triangle has exterior angles, one at each vertex, that measure 90°, $3x$°, and $3x$°. What is the value of x?

A 15

B 45

C 90

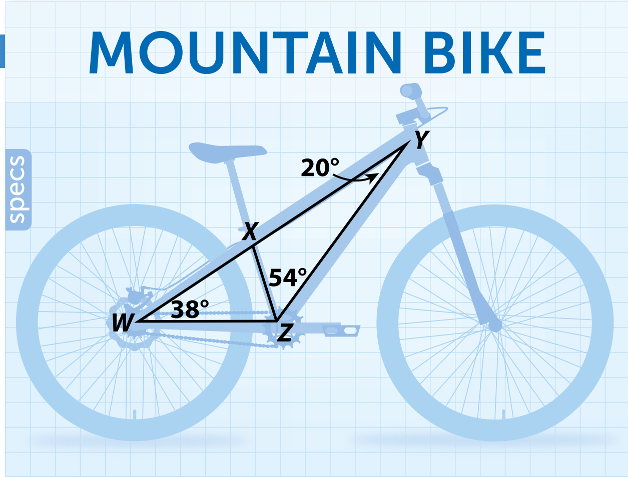
D 135

Zhen chose D as the correct answer. How might she have gotten that answer?

CONSIDER THIS . . .
What do you know about the exterior angle measures of a triangle?

PAIR/SHARE
Can you explain to a partner how you solved this problem?

4 The angles of a mountain bike frame are shown.



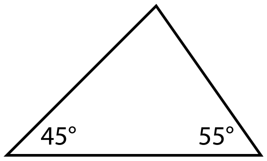
a. What is $m\angle WXZ$? Show your work.

SOLUTION ______________________________

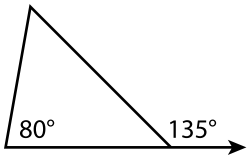
b. What is $m\angle XZW$? Show your work.

SOLUTION ______________________________

5 Which triangles are similar to the triangle at the right? Select all that apply.



A



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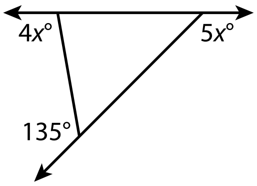
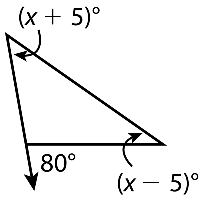
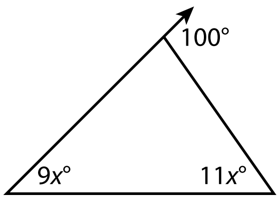


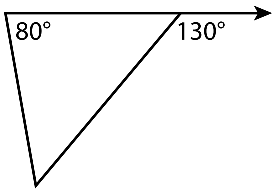
C



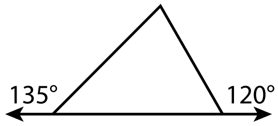
D



E



F



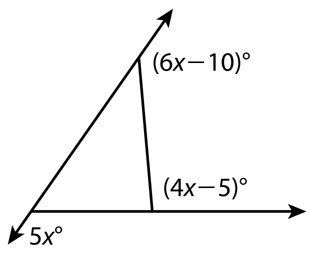
6 Can a triangle have an exterior angle that is obtuse at two vertices? Explain.

7 Tell whether each statement is *True* or *False*.

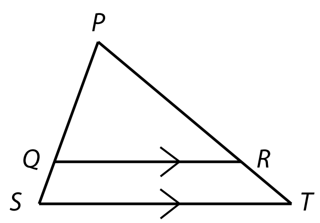
	True	False
a. A triangle can have more than one obtuse angle.	○	○
b. In a right triangle, the sum of the measures of the acute angles is 90°.	○	○
c. The measure of an exterior angle of a triangle is equal to the sum of the two nonadjacent interior angles.	○	○
d. The sum of the measures of the exterior angles of a triangle, one at each vertex, is 180°.	○	○

8 If all three angles of a triangle are congruent, what is each angle measure? Explain.

9 What is the value of *x*?



10 **Math Journal** The figure shows one triangle inside another. Are the two triangles similar? Explain.



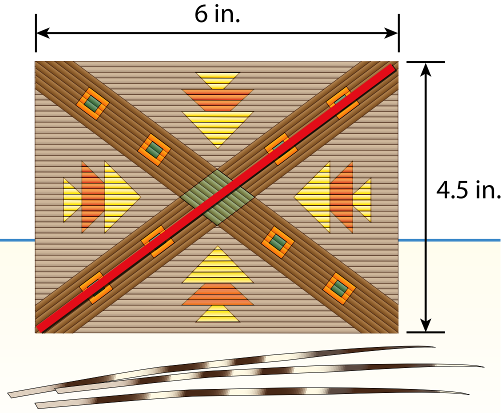
End of Lesson Checklist

☐ **INTERACTIVE GLOSSARY** Find the entry for *exterior angle*. Sketch an example of an exterior angle of a triangle.

☐ **SELF CHECK** Go back to the Unit 2 Opener and see what you can check off.

Explore Applying the Pythagorean Theorem

Previously, you learned about the Pythagorean Theorem. In this lesson, you will learn how to use the Pythagorean Theorem to solve problems involving right triangles.



➤ **Use what you know to try to solve the problem below.**

A Mi'kmaq (Mic-mac) artist uses porcupine quills to decorate a rectangular piece of leather. She places a row of porcupine quills extending from one corner to the opposite corner. Each quill measures 1.5 inches long. How many quills does the artist need to make her first diagonal?

TRY IT

Math Toolkit grid paper, rulers, unit tiles

DISCUSS IT

Ask: What did you do first to find the number of quills? Why?

Share: I knew . . . so I . . .

Learning Targets SMP 1, SMP 2, SMP 3, SMP 4, SMP 5, SMP 6, SMP 7

- Apply the Pythagorean Theorem to determine unknown side lengths in right triangles in real-world and mathematical problems in two and three dimensions.
- Apply the Pythagorean Theorem to find the distance between two points in a coordinate system.

CONNECT IT

1 Look Back How many quills are in the diagonal? How do you know?

2 Look Ahead

a. Fill in the blanks to restate the Pythagorean Theorem.

In any ____________ triangle, the sum of the squares of the lengths of the ____________ is equal to the square of the length of the ____________.

If a and b are the lengths of the legs of a right triangle and c is the length of the hypotenuse, then the theorem can be represented by the equation ____________.

b. When the side lengths of a right triangle are whole numbers, the lengths are known as *Pythagorean triples*. For example, the set of lengths 3, 4, 5 is a Pythagorean triple because $3^2 + 4^2 = 5^2$. Look at each set of three numbers shown on the right. Circle each set that is a Pythagorean triple.

c. Jason says that if you multiply each length in a Pythagorean triple by the same factor, you will get another Pythagorean triple. Explain why Jason is correct.

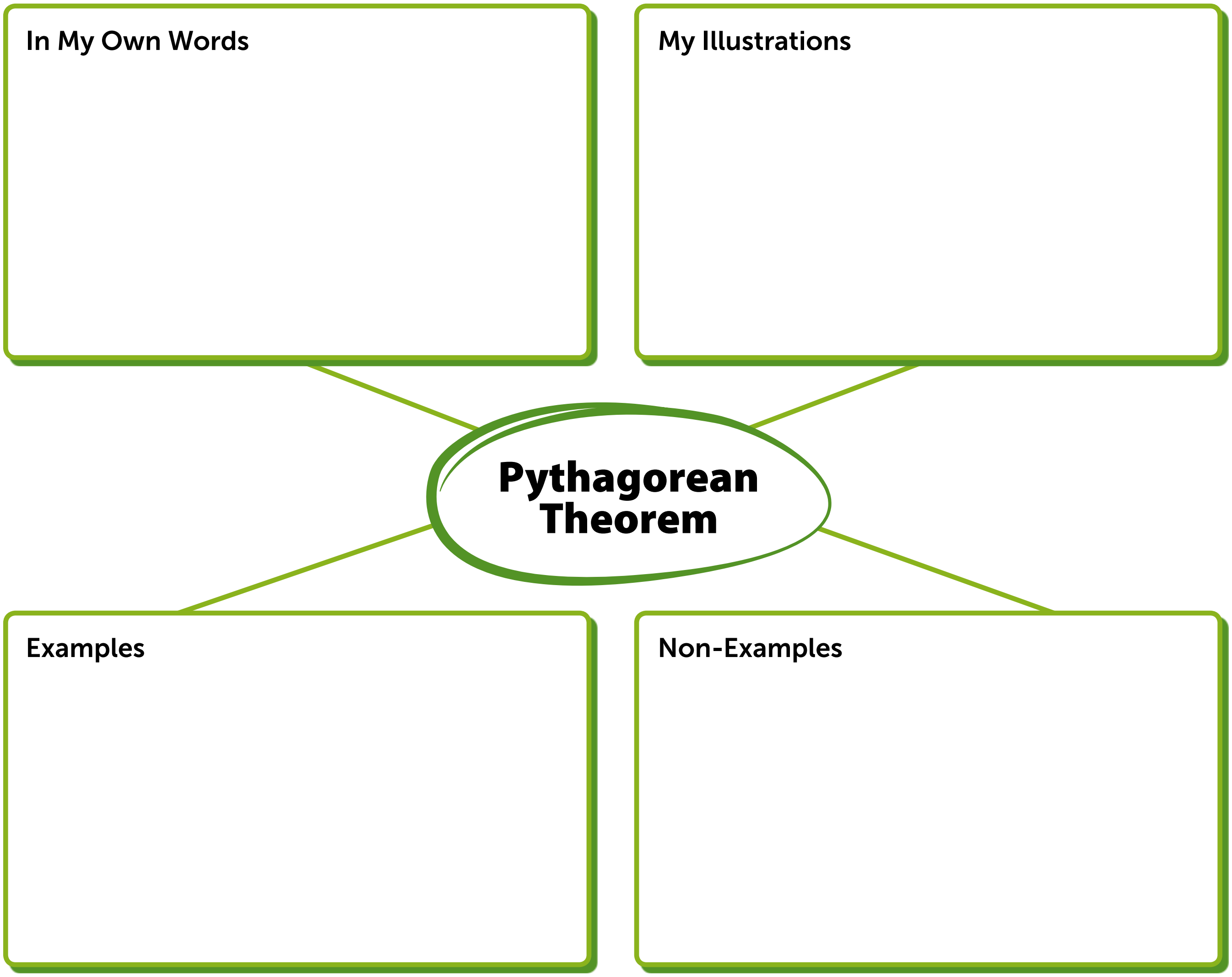
2, 3, 4
4, 5, 6
5, 12, 13
6, 8, 10
8, 15, 17
9, 16, 25

3 Reflect Give an example to show that a multiple of a Pythagorean triple is also a Pythagorean triple.

Name:

Prepare for Applying the Pythagorean Theorem

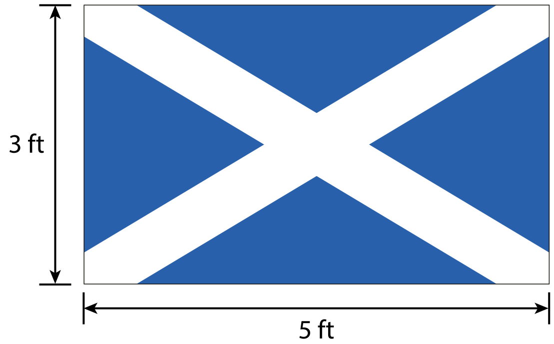
1. Think about what you know about right triangles. Fill in each box. Use words, numbers, and pictures. Show as many ideas as you can.



2. Suppose you have a right triangle with side lengths 26, 24, and 10. Which lengths represent the legs and which length represents the hypotenuse of the triangle? Use the Pythagorean Theorem to explain how you know.

3 The flag of Scotland consists of a blue rectangular background with two white diagonals.

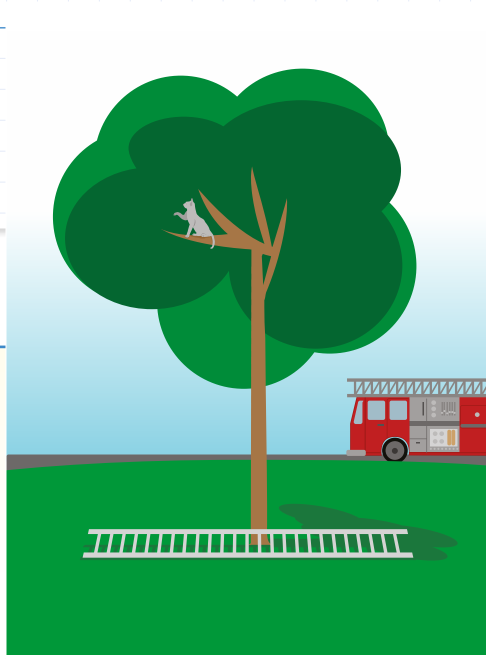
a. The dimensions of a Scottish flag are shown. If the flag's diagonals are made of white ribbon, what length of ribbon is needed for both diagonals? Show your work. Round your answer to the nearest foot.



SOLUTION ____________________

b. Check your answer to problem 3a. Show your work.

Develop Finding an Unknown Length in a Right Triangle



➤ **Read and try to solve the problem below.**

A firefighter is trying to rescue a kitten from a tree. He leans a 13-foot ladder so its top touches the tree. The base of the ladder is 5 feet from the base of the tree. The tree forms a right angle with the ground. How high up the tree does the ladder reach?

TRY IT

Math Toolkit centimeter grid paper, centimeter ruler, unit cubes

DISCUSS IT

Ask: Where does your model show the leg and the hypotenuse of the right triangle formed by the ground, tree, and ladder?

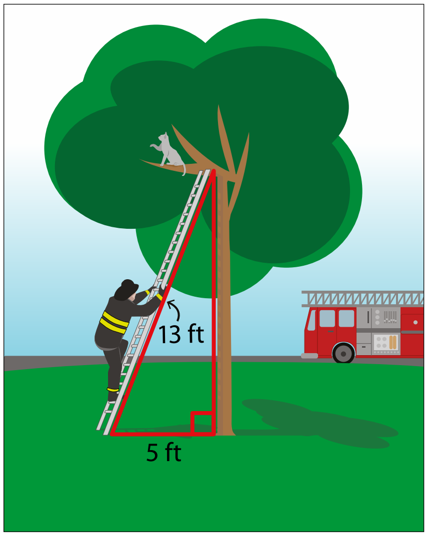
Share: In my model, . . . represents . . .

Explore different ways to find how to use the Pythagorean Theorem to find an unknown length.

A firefighter is trying to rescue a kitten from a tree. He leans a 13-foot ladder so its top touches the tree. The base of the ladder is 5 feet from the base of the tree. The tree forms a right angle with the ground. How high up the tree does the ladder reach?

Picture It

You can draw a picture to show the information you are given and what you still need to find.



Model It

You can use the Pythagorean Theorem.

The ladder represents the hypotenuse of the right triangle formed by the ladder, tree, and ground. Let b be the length you need to find.

$$5^2 + b^2 = 13^2$$

$$25 + b^2 = 169$$

$$b^2 = 169 - 25$$

$$b^2 = 144$$

$$b = \pm\sqrt{144}$$

CONNECT IT

➤ **Use the problem from the previous page to help you understand how to use the Pythagorean Theorem to find an unknown length.**

1 Look at **Picture It** and **Model It**. Explain how the picture and the equation $5^2 + b^2 = 13^2$ represent this situation.

2 **a.** How high up the tree does the ladder reach? Why do you not need to consider the negative square root of b?

b. When using the Pythagorean Theorem to find an unknown length, do you ever need to consider a negative square root? Explain.

3 A right triangle has leg lengths a and b and hypotenuse length c. Write a subtraction equation that you could use to solve for b. Write a subtraction equation that you could use to solve for a.

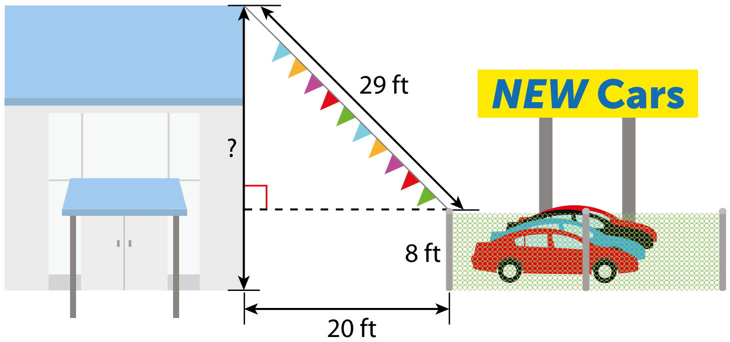
4 When might you use one of the equations in problem 3? Why?

5 **Reflect** Think about all the models and strategies you have discussed today. Describe how one of them helped you better understand how to solve the **Try It** problem.

Apply It

➤ **Use what you learned to solve these problems.**

6 A car salesman is stringing banners from the top of the roof to a fence pole 20 feet away. The fence pole is 8 feet high. He uses 29 feet of banner rope to reach from the rooftop to the fence pole. How tall is the roof? Show your work.



SOLUTION ____________________

7 Which set of side lengths do not form a right triangle?

A 5, 6, $\sqrt{61}$

B 24, 7, 25

C 14, 7, $\sqrt{245}$

D 12, 15, 18

8 The perimeter of an equilateral triangle is 48 cm. Find the height of the triangle to the nearest whole number. Show your work.

SOLUTION ____________________

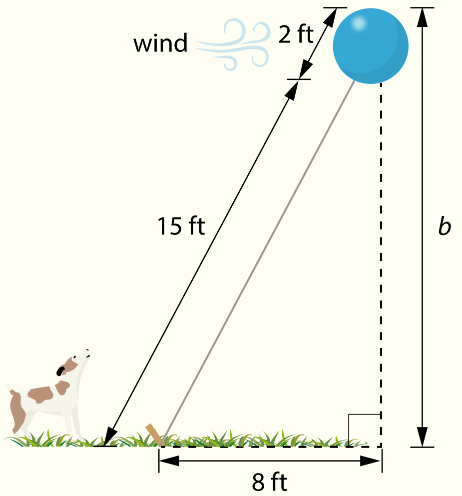
Name:

Practice Finding an Unknown Length in a Right Triangle

Study the Example showing how to find an unknown length in a right triangle. Then solve problems 1–4.

Example

A meteorologist ties a spherical balloon that is 2 feet in diameter to a stake in the ground. The string is 15 feet long. The wind blows the balloon so that the top of it is 8 feet to the right of the stake. What is the distance, *b*, from the top of the balloon to the ground?



Use a right triangle. The lengths of the hypotenuse and one leg are known. Use the Pythagorean Theorem to find the length of the other leg.

$b^2 = c^2 - a^2$

$b^2 = 17^2 - 8^2$

$b^2 = 289 - 64$

$b^2 = 225$

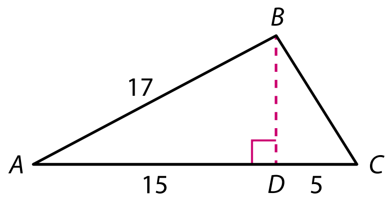
$b = \sqrt{225}$ or 15

The distance from the top of the balloon to the ground is 15 ft.

1. Imani used the equation $8^2 + b^2 = 17^2$ to find the distance from the top of the balloon to the ground in the Example. Why does this equation also work?

2. Kamal said the distance from the top of the balloon to the ground in the Example is $\sqrt{353}$ ft. What mistake might Kamal have made?

3 The diagram shows $\triangle ABC$.



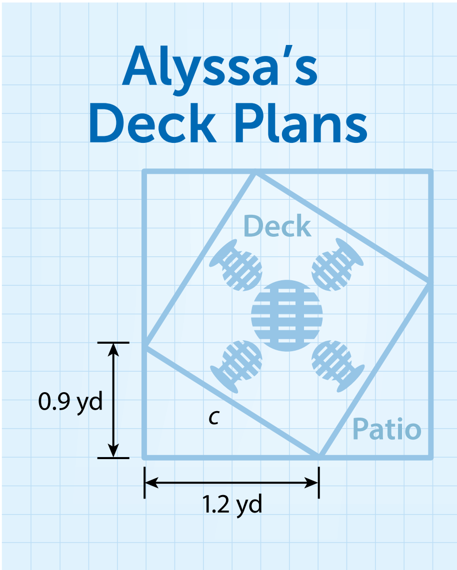
a. What is the height of $\triangle ABC$? Show your work.

SOLUTION ______________________________

b. What is the length of $\overline{BC}$ in $\triangle ABC$? Show your work.

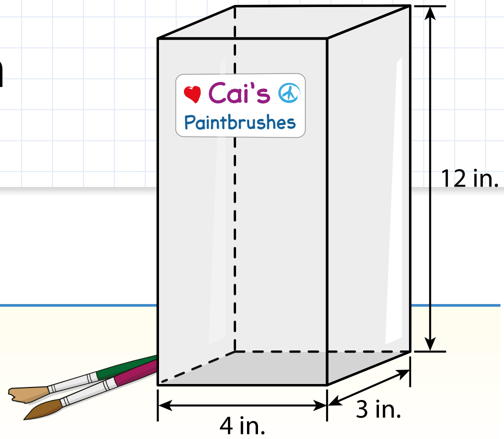
SOLUTION ______________________________

4 Alyssa is designing a square wooden deck with side length c yards. She will build the deck over her square patio, as shown in the diagram. Find the perimeter of the deck. Show your work.



SOLUTION ______________________________

Develop Finding an Unknown Length in a Three-Dimensional Figure



Read and try to solve the problem below.

Cai has a box for her paintbrushes. The box is a right rectangular prism. What is the longest paintbrush that will fit in the box?

TRY IT

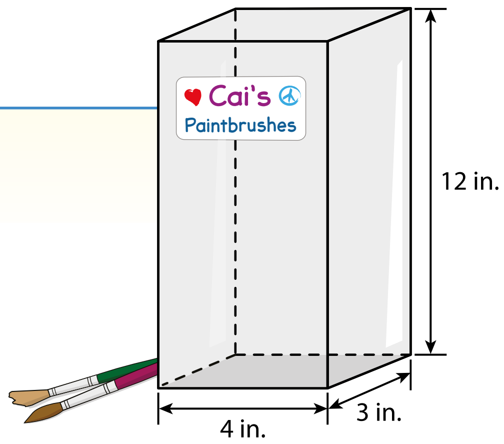
Math Toolkit grid paper, rulers

DISCUSS IT

Ask: Why did you choose that strategy to find the longest paintbrush that will fit?

Share: The problem is asking . . .

Explore different ways to find an unknown length in a right rectangular prism.

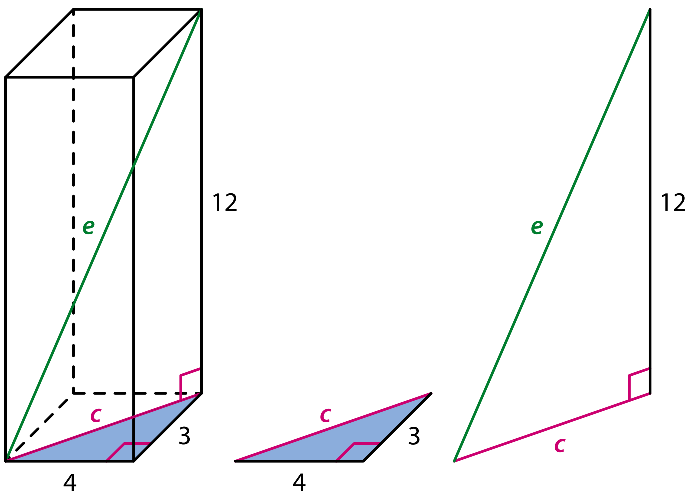


Cai has a box for her paintbrushes. The box is a right rectangular prism. What is the longest paintbrush that will fit in the box?

Picture It

You can draw a diagram to represent the problem.

Look for right triangles that can help you find the length you need.



You can use the diagonal length of the base, c, to find the diagonal length of the box, e.

Model It

You can use the Pythagorean Theorem to write equations.

To find the diagonal length of the base: $3^2 + 4^2 = c^2$

To find the diagonal length of the box: $c^2 + 12^2 = e^2$

Substitute to get one equation: $3^2 + 4^2 + 12^2 = e^2$

CONNECT IT

➤ **Use the problem from the previous page to help you understand how to find an unknown length in a right rectangular prism.**

1. Look at **Picture It** and **Model It**. How does finding the length of diagonal c help you find the length of diagonal e?

2. Solve the last equation in **Model It** to find e. What is the longest paintbrush that will fit in the box?

3. Tyrone says you can also solve the problem by first solving $3^2 + 4^2 = c^2$ for c and then using this value of c to solve $c^2 + 12^2 = e^2$ for e. Is Tyrone correct? Explain.

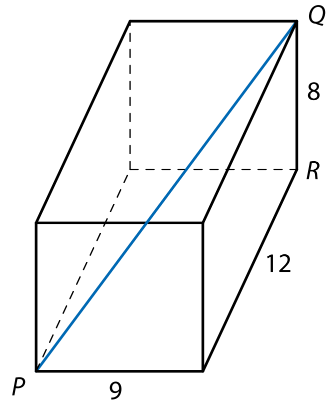
4. When can you use the Pythagorean Theorem to find an unknown length in a right rectangular prism?

5. **Reflect** Think about all the models and strategies you have discussed today. Describe how one of them helped you better understand how to solve the **Try It** problem.

Apply It

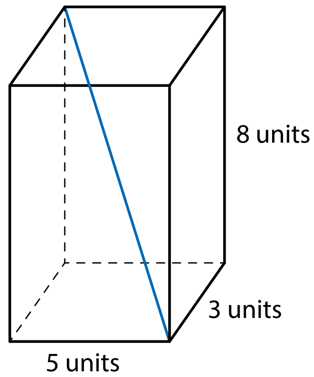
➤ **Use what you learned to solve these problems.**

6 Find the length of the diagonal from *P* to *Q* in this right rectangular prism. Show your work.



SOLUTION ______________________________

7 What is the distance from one corner of the bottom base to the opposite corner of the top base in this right rectangular prism?



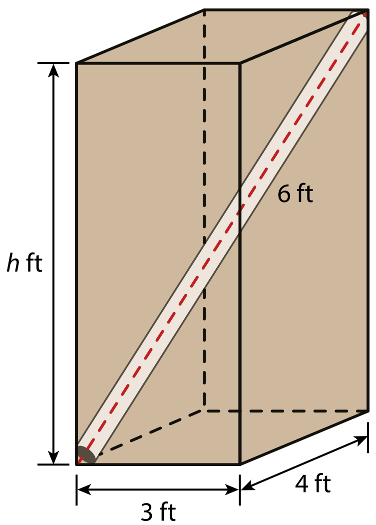
A $\sqrt{34}$ units

B $\sqrt{80}$ units

C $\sqrt{89}$ units

D $\sqrt{98}$ units

8 Anica is shipping a poster to a customer. When the poster is rolled up, it measures 6 feet long. She will use a box that is a right rectangular prism with a base that is 3 feet by 4 feet. What whole number could be the shortest height of the box that will hold the poster?
Show your work.



SOLUTION ______________________________

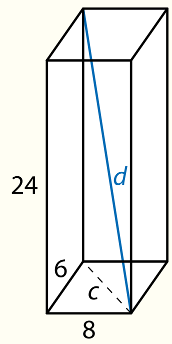
Practice Finding an Unknown Length in a Three-Dimensional Figure

➤ **Study the Example explaining how to find the length of a diagonal in a right rectangular prism. Then solve problems 1–4.**

Example

The diagram shows a diagonal drawn in a right rectangular prism. Explain how you can find *d*, the length of this diagonal.

Look for right triangles. Side length *d* is the hypotenuse of the right triangle with leg lengths *c* and 24. Side length *c* is the hypotenuse of the right triangle in the base of the prism with leg lengths 6 and 8. Use the Pythagorean Theorem to find *c*. Then use it again to find *d*.



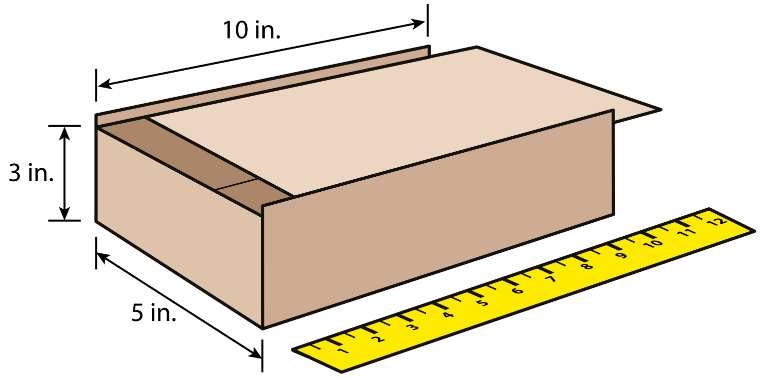
1 **a.** How do you know that the triangle with side lengths 6, 8, and *c* in the Example is a right triangle?

b. How do you know that the triangle with side lengths *c*, 24, and *d* in the Example is a right triangle?

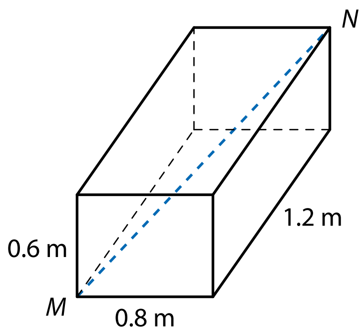
2 What is the length of the diagonal *d* in the Example? Show your work.

SOLUTION ______________________________

3 Will a 12-inch ruler fit in a box that is a right rectangular prism with a width of 5 inches, a length of 10 inches, and a height of 3 inches? Explain your answer.



4 In the right rectangular prism, what is the length of the diagonal from M to N to the nearest tenth of a meter? Show your work.

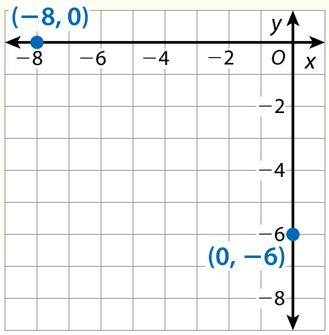


SOLUTION ______________________________

Develop Finding Distance in the Coordinate Plane

Read and try to solve the problem below.

Find the shortest distance between the points (0, −6) and (−8, 0).



TRY IT

Math Toolkit compasses, graph paper, rulers, tracing paper

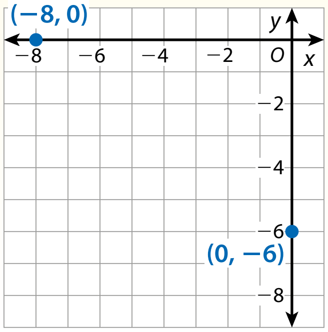
DISCUSS IT

Ask: How did you get started?

Share: I started by . . .

➤ Explore different ways to find the distance between points in the coordinate plane.

Find the shortest distance between the points $(0, -6)$ and $(-8, 0)$.

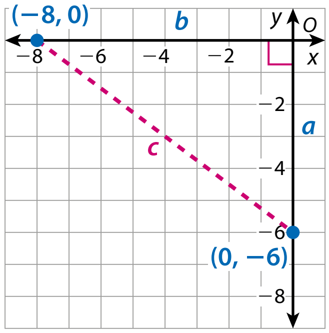


Picture It

You can draw a right triangle.

Draw a line segment between the points. Then draw a right triangle so the distance between the points is the hypotenuse.

In the right triangle, ***a*** and ***b*** are the lengths of the legs and ***c*** is the length of the hypotenuse.



Model It

You can use the Pythagorean Theorem to find the unknown distance.

$a^2 + b^2 = c^2$

$6^2 + 8^2 = c^2$

CONNECT IT

➤ **Use the problem from the previous page to help you understand how to find the distance between two points in the coordinate plane.**

1 Look at **Picture It**. How do you know the triangle formed by the two points and the origin is a right triangle?

2 Jessica said the lengths of the legs are -6 units and -8 units. What mistake did Jessica make? What are the correct lengths of the legs?

3 Look at **Model It**. What is the distance between $(0, -6)$ and $(-8, 0)$? Why can you use the Pythagorean Theorem to find this distance?

4 Why is it important that the distance between $(0, -6)$ and $(-8, 0)$ be the hypotenuse of the right triangle and not a leg?

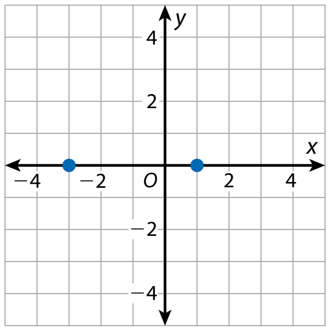
5 Explain how to find the distance between any two points in the coordinate plane that do not lie on the same horizontal or vertical line.

6 **Reflect** Think about all the models and strategies you have discussed today. Describe how one of them helped you better understand how to find the distance between two points in the coordinate plane.

Apply It

Use what you learned to solve these problems.

7 Hailey plots the first two vertices of a right triangle in the coordinate plane. Where could she plot the third point so the hypotenuse of the triangle has a length of 5 units?



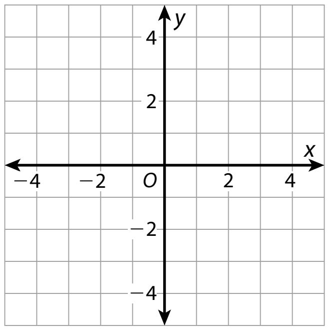
A (1, 5)

B (−3, 4)

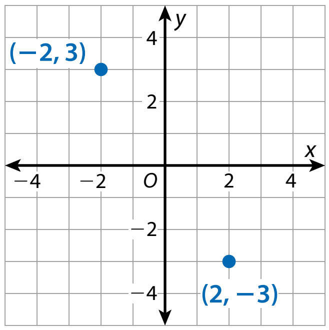
C (0, −5)

D (1, −3)

8 Draw a line segment from the origin (0, 0) with length $\sqrt{20}$. Show your work.



9 Find the distance between the points shown. Show your work.



SOLUTION ______________________________

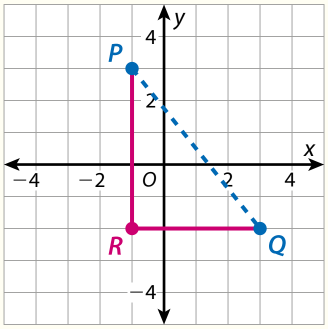
Name:

Practice Finding Distance in the Coordinate Plane

Study the Example showing how to find the distance between two points in the coordinate plane. Then solve problems 1–3.

Example

What is the distance between $P(-1, 3)$ and $Q(3, -2)$ in the coordinate plane?



Draw a right triangle with $R(-1, -2)$ as the vertex of the right angle. Then use the Pythagorean Theorem to find the length of the hypotenuse, which is the distance between P and Q.

$QR = 4$ units, $RP = 5$ units, $PQ = c$ units

$$4^2 + 5^2 = c^2$$
$$16 + 25 = c^2$$
$$41 = c^2$$
$$\sqrt{41} = c$$

The distance between $P(-1, 3)$ and $Q(3, -2)$ is $\sqrt{41}$ units.

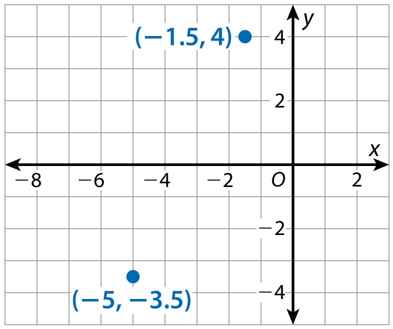
1 Look at the Example.

a. Describe another right triangle you could draw from points $P(-1, 3)$ and $Q(3, -2)$.

b. Will your triangle from problem 1a give you the same distance between points P and Q? Explain.

c. Would drawing a triangle with points $(-1, 3)$, $(3, -2)$, and $(3, 2)$ as vertices help you find the distance between the points? Explain.

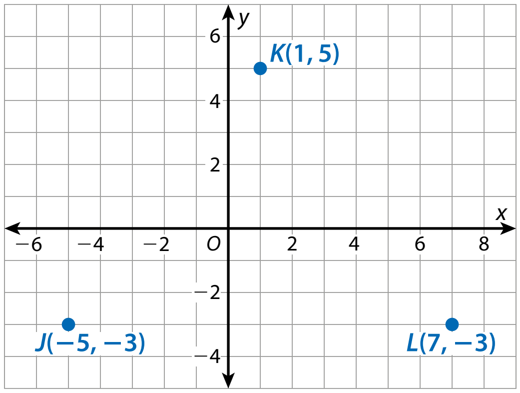
2 What is the distance between the points shown? Show your work. Round your answer to the nearest tenth.



SOLUTION ______________________________

3 Dr. Patel plots points *J*, *K*, and *L* in the coordinate plane.

a. What is the distance between points *J* and *K*? Show your work.



SOLUTION ______________________________

b. What is the distance between points *K* and *L*? Show your work.

SOLUTION ______________________________

c. Is △*JKL* an equilateral triangle? Explain.

Refine Applying the Pythagorean Theorem

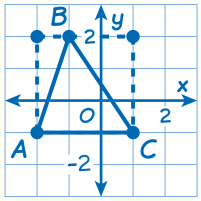
➤ **Complete the Example below. Then solve problems 1–8.**

Example

Chase drew a triangle with vertices at (−2, −1), (−1, 2), and (1, −1). Classify Chase's triangle as scalene, isosceles, or equilateral.

Look at how you could use the Pythagorean Theorem.

Draw a right triangle at each nonvertical and nonhorizontal side of the original triangle.



$\overline{AB}$: $1^2 + 3^2 = AB^2$

$AB^2 = 10$, so $AB = \sqrt{10}$.

$\overline{BC}$: $2^2 + 3^2 = BC^2$

$BC^2 = 13$, so $BC = \sqrt{13}$.

$\overline{AC}$: $AC = 3$

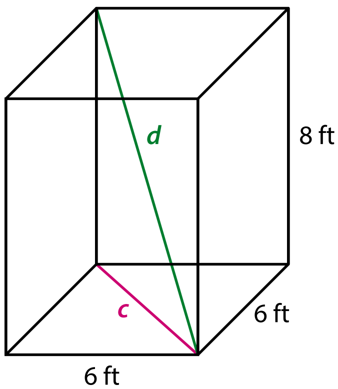
SOLUTION ______________________________

CONSIDER THIS . . .
An isosceles triangle has at least two congruent sides. A scalene triangle has no congruent sides.

PAIR/SHARE
How else could you solve this?

Apply It

1 Mr. Gaspar wants to store a 12-foot-long pipe in a tool closet. The closet has the shape of a right rectangular prism with the dimensions shown. Will the pipe fit? Show your work.

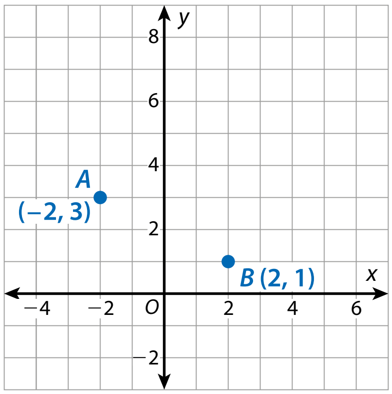


SOLUTION ______________________________

CONSIDER THIS . . .
This problem takes more than one step to solve.

PAIR/SHARE
Can you find two different paths to the solution? Explain.

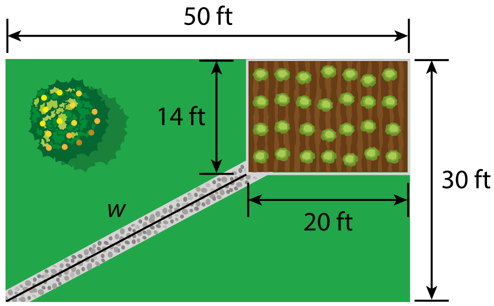
2 $\overline{AB}$ is one side of a square. Find the coordinates of the other two vertices of the square and draw the square. Explain your reasoning.



CONSIDER THIS . . .
How could a right triangle help you find the side length of the square?

PAIR/SHARE
How else could you solve this?

3 Mr. Shaw is building a walkway from the corner of his house out to his vegetable garden in the corner of the yard. The dimensions of the yard and the garden are shown. What is the length of the walkway, *w*, to the nearest foot?



A 24 ft

B 34 ft

C 46 ft

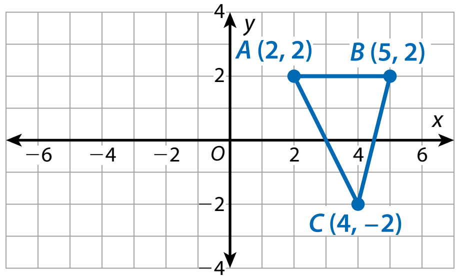
D 58 ft

Ummi chose C as the correct answer. How might she have gotten that answer?

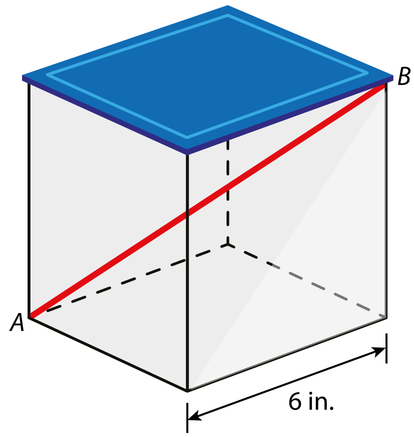
CONSIDER THIS . . .
Where can you draw a useful right triangle?

PAIR/SHARE
Was there more than one helpful right triangle that would lead to the solution?

4 Draw the reflection of $\triangle ABC$ across the y-axis. Then show that the corresponding sides of the two triangles are congruent.



5 A small plastic storage cube has a side length of 6 inches. What is the length of $\overline{AB}$ to the nearest tenth of an inch?



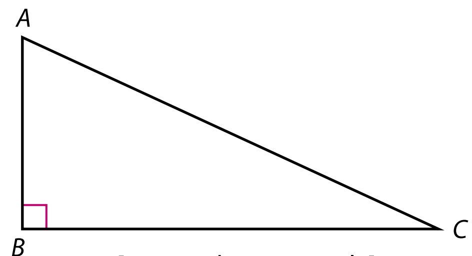
A 6 in.

B 8.5 in.

C 10.4 in.

D 12 in.

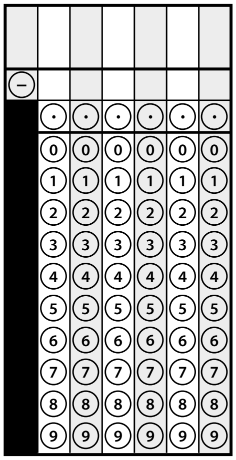
6 In $\triangle ABC$, $\overline{BC}$ is longer than $\overline{AB}$, and $BC = 24$. $\overline{AB}$ and $\overline{CA}$ have whole-number lengths. Tell whether each side length is *Possible* or *Not Possible*.

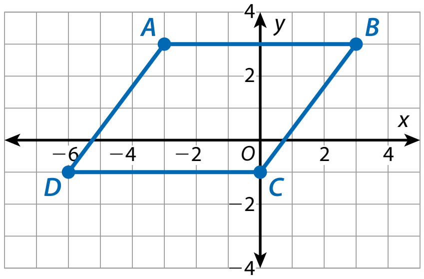


[Art not drawn to scale]

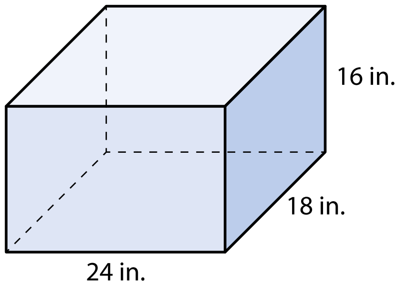
	Possible	Not Possible
a. $AB = 7$	◯	◯
b. $AB = 9$	◯	◯
c. $AB = 10$	◯	◯
d. $CA = 25$	◯	◯

7 What is the perimeter of parallelogram *ABCD*?





8 **Math Journal** José is mailing some baseball equipment to his cousin. He wants to include a baseball bat that is 33 in. long. Will the baseball bat fit completely in the box? Explain your reasoning.



End of Lesson Checklist

- ☐ **INTERACTIVE GLOSSARY** Write a new entry for *consider*. Tell what you do when you consider something.
- ☐ **SELF CHECK** Go back to the Unit 6 Opener and see what you can check off.