Welding – Cutting Pipe

Math Module

Cutting Pipe to Length, Determining Tension

Jack has just landed his first job as welder. Working as a welder that he connect together pieces of metal. He is working on projects involve steel bracing. He needs to know how to find the lengths of sides of a right triangle to make the braces. He also needs to know how to determine the maximum load capability when lifting large pieces of steel. Jack learned a lot of math while he was in his welding program.

Focus

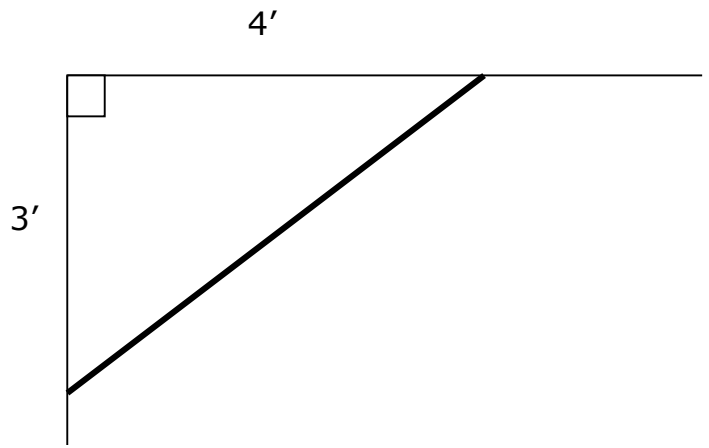
The focus of this math strand is for you to be able to find the lengths of the sides of right triangles and to determine the maximum load capability.

In this math strand you'll be learning and/or reviewing the following math skills:

1) Determining Units of Measure
2) Working with Formulas
3) Finding the Square Root
4) Working with Angles
5) Reading Tables
6) Working with Triangles
7) Problem Solving
8) Working with Exponents
9) Rounding
10) Converting Units of Measure

Task One: Find the Length of a Side in a Right Triangle

Jack is creating bracing. (You can see bracing in the picture below.) The bracing will be attached to reinforce two perpendicular (forms a 90 degree angle) sides of a structure. He needs to determine the length needed for the bracing. The bracing will be attached 3' (' means feet) down and 4' to the right of the corner (see diagram). The Pythagorean Theorem is the formula needed to find the correct length of the bracing.

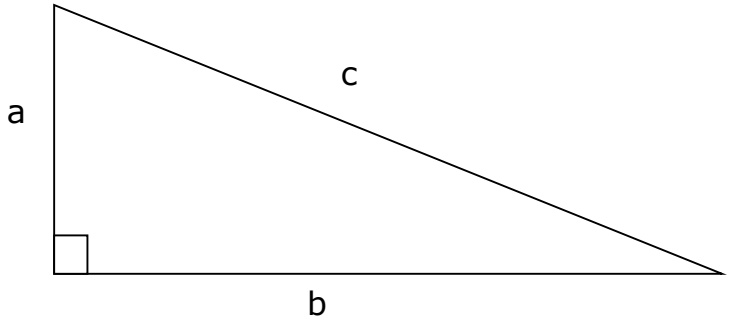


Listen

Listen and follow along as Jack explains the Pythagorean Theorem.

"The Pythagorean Theorem is a formula that is used to find one side of a right triangle when the other two sides are known. A right triangle is a triangle in which one of the angles is a 90 degree angle. The Pythagorean Theorem states that the sum of the squares of the lengths of the legs (the two shortest sides) of a right triangle is equal to the square of the length of the hypotenuse (the longest side).

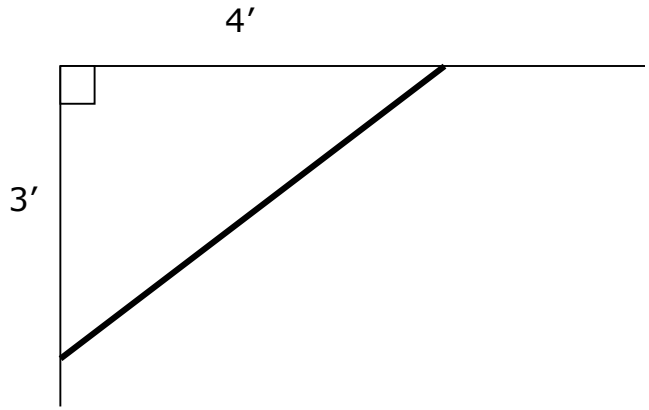
Most people memorize the Pythagorean Theorem by the formula $a^2 + b^2 = c^2$



Listen

The "a" and "b" are the lengths of the legs and the "c" is the length of the hypotenuse. The hypotenuse is always across from the right angle and the legs are the two sides that come together to make the right angle.

The brace that I'm cutting is the length of the hypotenuse of a right triangle. Remember I am working on determining the length of a brace needed for the situation shown below."



Think About It!

What are the values of a, b, and c in the problem Jack is solving?

The values of a and b are 3 and 4. The values of and a and b are the legs. Since 3 and 4 are the legs you can use either one for a or b. You can use a = 3 and b = 4 or a = 4 and b = 3. The value of c is the length that Jack is trying to find. It is unknown, so we will continue to call it c.

Pythagorean Theorem

Jack knows the values of a and b are 3 and 4. When he substitutes those values into the Pythagorean Theorem he gets:

$$3^2 + 4^2 = c^2$$

The next step in solving for c (finding the length of the pipe) is to find the values of 3^2 and 4^2. The little 2 above the 3 and 4 is called an exponent. An exponent means to multiply the number (called the base) by itself as many times as the value of the exponent. For example, 6^2 means 6 x 6 which is 36. Therefore $6^2 = 36$.

If the exponent is a 3, multiply the number by itself 3 times.

$$5^3 = 5 \times 5 \times 5 = 125$$

Practice

A. Find the value of each of the following.

1) 7^2 — 7 x 7 = 49

2) 2^3 — 2 x 2 x 2 = 8

3) 10^4 — 10 x 10 x 10 x 10 = 10,000

4) $(1.4)^2$ — 1.4 x 1.4 = 1.96

5) $\left(\frac{2}{3}\right)^2$ — 2/3 x 2/3 = 4/9

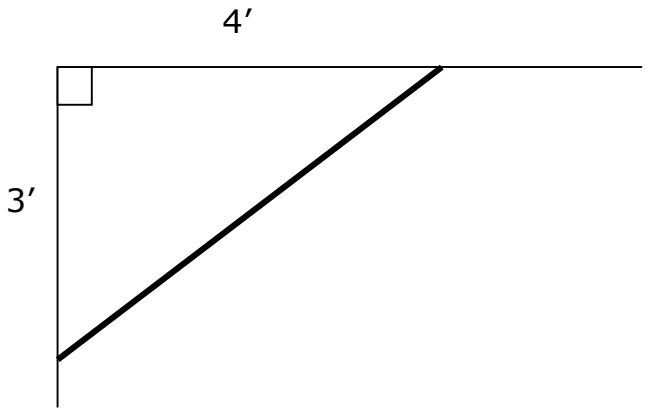
Practice

Click here for more practice multiplying decimals.

Click here for more practice multiplying fractions.

Finding the Length of the Pipe

Now that you are comfortable with exponents, let's get back to Jack's problem. He is trying to find the length of a pipe for a bracing that will be attached 3 feet down and 4 feet over from the corner of two perpendicular sides.



Think About It!

After the exponents are simplified in the equation $3^2 + 4^2 = c^2$, what will the new equation be?

$9 + 16 = c^2$

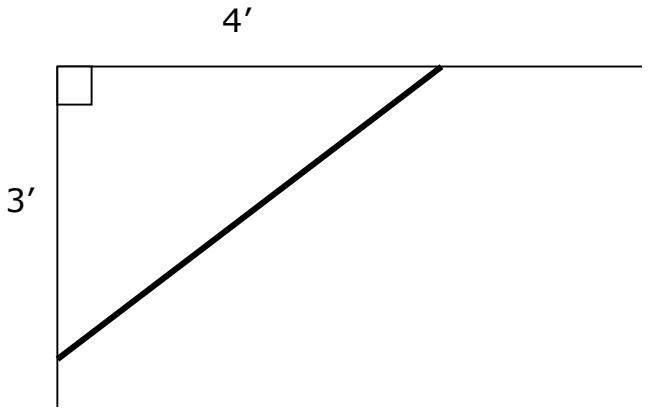
Finding the Length of the Pipe

In order to find the length of the pipe Jack needs to find the value of c. We now have $9 + 16 = c^2$. The next step is to add the 9 and the 16 and we have

$$25 = c^2$$

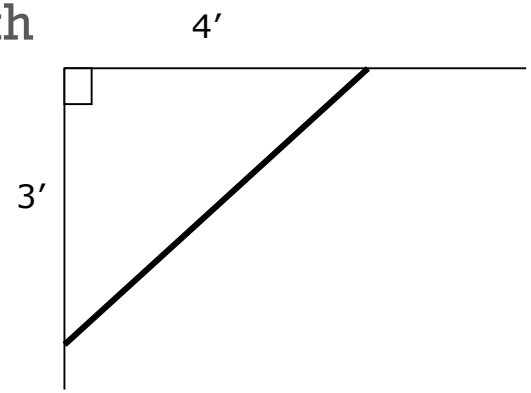
Remember that c^2 means c x c. So we are looking for a number that when multiplied by itself is 25. Do you know what number that when multiplied by itself is 25?

5, Because 5 x 5 = 25



Finding the Length of the Pipe

A solution to the equation $25 = c^2$ is 5. (The other solution to this equation is -5, but since we are looking for a length, a negative number does not make sense so we will disregard this other solution. Throughout the remainder of this section, we will disregard the negative solutions.) The length that Jack needs is 5 feet. Let's go back and review how that problem was solved.



1) Set up the equation $\mathbf{3^2 + 4^2 = c^2}$
2) Simplify the exponents $\mathbf{9 + 16 = c^2}$
3) Add the numbers together $\mathbf{25 = c^2}$
4) Determine what number that when multiplied by itself is 25 $\mathbf{5 = c}$

Practice

B. Solve the problem using the four steps listed on the previous screen.

The next brace that Jack needs to make will be placed 5" (" means inches) down and 12" to the right. What length does Jack need?

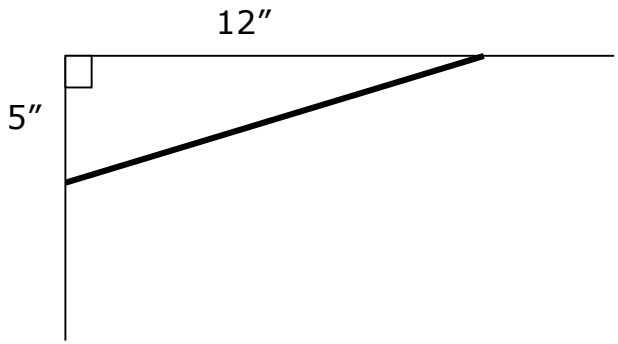
1) What is the equation? $5^2 + 12^2$ the equation $= c^2$

2) What is with the exponents simplified? $25 + 144 = c^2$

3) What is the equation with the numbers added? $169 = c^2$

4) What is the answer?

13 = c, because 13 x 13 = 169. So the length of pipe Jack needs is 13"



Using Your Calculator

The last step of this problem was to determine what number that when multiplied by itself is 169. There is an easy was to determine the answer. It is called taking the square root. The symbol for square root is $\sqrt{\ }$. To find what number when multiplied by itself is 169, find the square root button on your calculator and type in $\sqrt{169}$. It should say 13.

If you can see the $\sqrt{\ }$ on the screen when you type it in, then you will type the $\sqrt{\ }$ button and then the number. If you can't see the symbol on your screen, then you type in the number first and then the $\sqrt{\ }$. Each calculator is little different. You may also need to use the shift button to access the square root.

Practice

C. Use your calculator to find the following.

1) $\sqrt{6724}$ — 82

2) $\sqrt{68.89}$ — 8.3

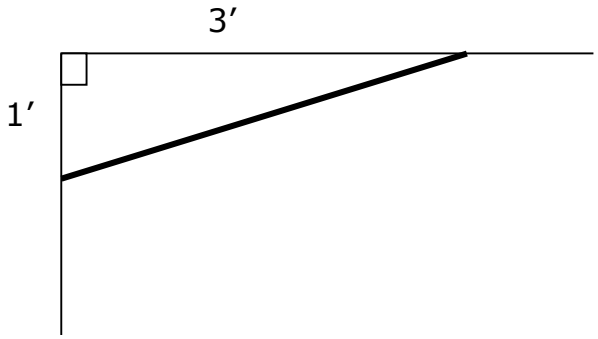
3) $\sqrt{225}$ — 15

4) $\sqrt{0}$ — 0

5) $\sqrt{1{,}000{,}000}$ — 1000

Finding the Length of the Pipe

The next piece Jack has to cut is shown in the diagram at the right. In order to find out the length he needs Jack uses the Pythagorean Theorem.



$1^2 + 3^2 = c^2$

$1 + 9 = c^2$

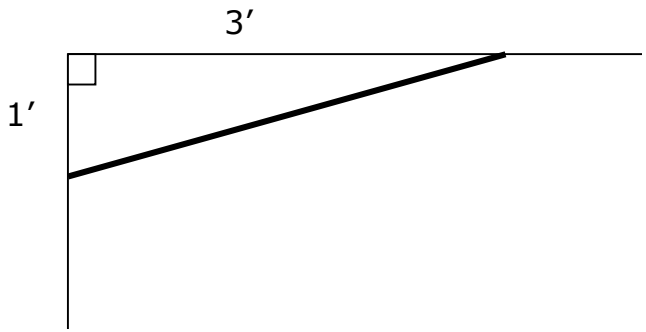
$10 = c^2$

Now he is at the point in the problem where he has to find what number that when multiplied by itself is 10. There are some numbers in which there is no whole number that when multiplied by itself equals that number. For example, what number that when multiplied by itself is 10?

We know 3 x 3 = 9 and 4 x 4 = 16. The number that when multiplied by itself is 10, must be a little bigger than 3, since 3 x 3 = 9, but still less that 4.

Finding the Length of the Pipe

Type $\sqrt{10}$ into your calculator. It should say 3.16227766… depending on how many digits your calculator screen can display. So 3.16227766… multiplied by itself is 10. This number goes on for an infinite (forever) number of digits and never establishes a repeating pattern. This is called an irrational number. Now Jack knows the length of the pipe he needs is **3.16227766… feet = c**



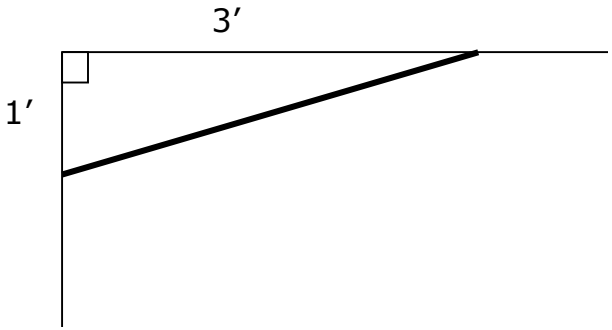
Click here for more practice rounding.

Finding the Length of the Pipe

When working with measurements like this it is usually necessary to round, because at some point past the decimal the values become insignificant. The value of rounded to the nearest:

tenth is 3.2
hundredth is 3.16
thousandth is 3.162

If Jack were rounding to the nearest tenth, he would need a piece of pipe that is 3.2' long.



Practice

C. Find the length needed for each of the following braces. The first length given is how far down from the corner the brace is attached and the second length is how far over. Round your answers to the nearest tenth, if necessary.

1) 6 inches, 8 inches

10 inches

2) 1 foot, 2 feet

2.2 feet

3) 11 cm, 11 cm

15.6 cm

4) 1 foot 5 inches, 1 foot 5 inches (Hint: convert to inches)

24.0 inches or 2 feet

5) 8 ¼ inches, 10 ½ inches (Hint: convert fractions to decimals)

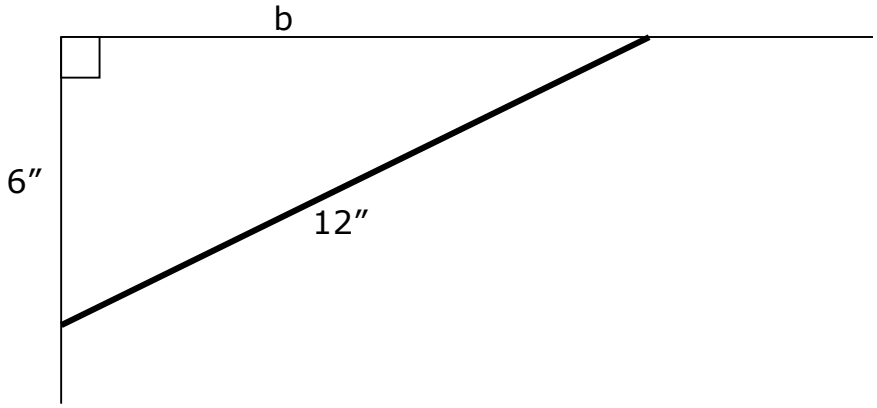
13.4 inches

For more practice converting a fraction to a decimal, click 1, 2, or 3.

Finding the Length of the Leg of a Right Triangle

Jack has a brace that is 12 inches long. is going to attach it 6 inches down from the corner. How far over from the corner will the brace be attached?

In this problem Jack knows the value of c, the hypotenuse, but he does not know the length of one of the legs, b.



Think About It!

What are the values of a, b, and c?

a = 6 and c = 12. We don't know the value of b, so we will just call it b.

Finding the Length of the Leg of a Right Triangle

What is the equation needed to find the value of b?

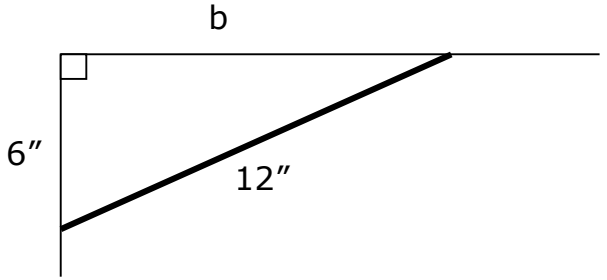
$(6^2 + b^2 = 12^2)$

To solve this equation, simplify the exponents and get:

$$36 + b^2 = 144$$

Since we are finding the value of b we need to subtract 36 from both sides of the equation:

$$\begin{array}{r} 36 + b^2 = 144 \\ -36 \quad -36 \\ \hline b^2 = 108 \end{array}$$



Lastly to find what number that when multiplied by itself is 108, take the square root of 108:

$$b = 10.39230485\ldots$$

Steps

Let's round this answer to the nearest tenth. The distance from the corner the brace will be attached is approximately 10.4 inches.

If you know the length of one leg and the length of hypotenuse in a right triangle, you can find the length of the other leg using these steps:

1) Write the equation
2) Simplify the exponents
3) Subtract the leg squared from both sides of the equation
4) Take the square root

Finding the Length of the Leg of a Right Triangle

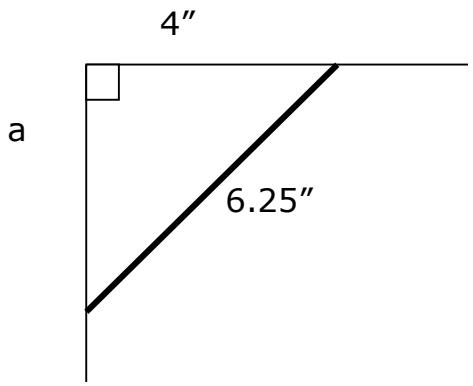
Let's look at another similar situation:
This brace is 6.25 inches long and is attached at point 4 inches from the corner. How far down the wall will the brace be attached? Round to the nearest hundredth.

1) Write the equation $a^2 + 4^2 = 6.25^2$
2) Simplify the exponents $a^2 + 16 = 39.0625$
3) Subtract the leg squared from both sides of the equation

$$a^2 + 16 = 39.0625$$
$$-16 \quad -16$$
$$a^2 = 23.0625$$

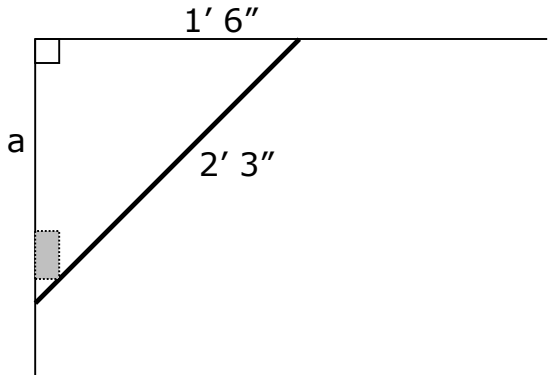
4) Take the square root

$$a = \sqrt{23.0625}$$
$$a \approx 4.80 \text{ inches}$$



Finding the Length of the Leg of a Right Triangle

The next brace that Jack is welding into place is 2 feet 3 inches long and will be attached at a point 1 foot 6 inches from the corner. In order to clear an outlet he needs it to reach at least 1 foot 6 inches below the corner. Will he clear the outlet?



Practice

1) What is the equation? (Hint: convert all measures to inches)

$a^2 + 18^2 = 27^2$, because there are 12" in 1', 1'6" = 18" and 2'3" = 27"

2) What is the equation with the exponents simplified?

$a^2 + 324 = 729$

3) What is the equation after the leg squared is subtracted from both sides of the equation?

$a^2 = 405$

Practice

4) What is the length of a to the nearest tenth of an inch?

20.1 inches

5) How many feet and inches is that?

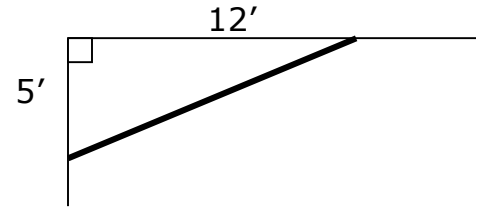
1' 8.1", There are 12" in a foot 20.1 – 12 = 8.1, so 20.1" = 1' 8.1"

6) Will Jack clear the outlet?

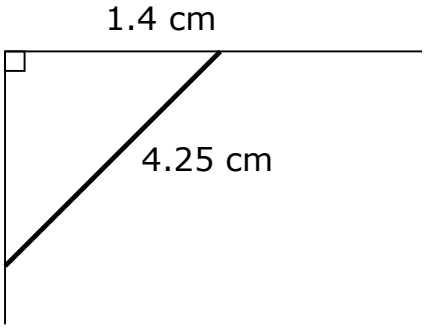
Yes! He needed to clear 1' 6" and the brace will be attached at 1' 8.1" from the corner.

Practice

D. Find the missing lengths using the Pythagorean Theorem. Round your answers to the nearest tenth, if necessary.

1) 

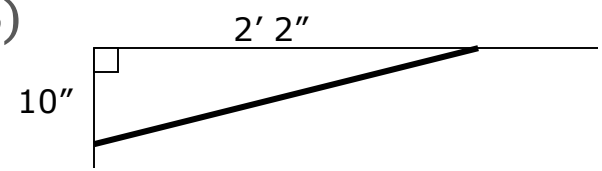
13’

2) 

4.0 cm

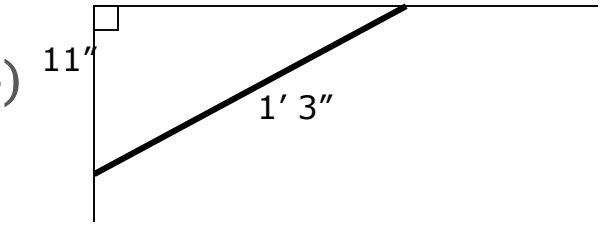
Practice

3)



2’ 3.9”

4)



10.2”

Practice

5) Jack is welding a brace into place that is 22.5 cm long and needs to clear an outlet that is 16 cm below the corner.

a) If he attaches the brace at a point 16.5 cm to the right of the corner. Will he clear the outlet?

No, the brace will touch the wall at a point 15.3 cm below the corner.

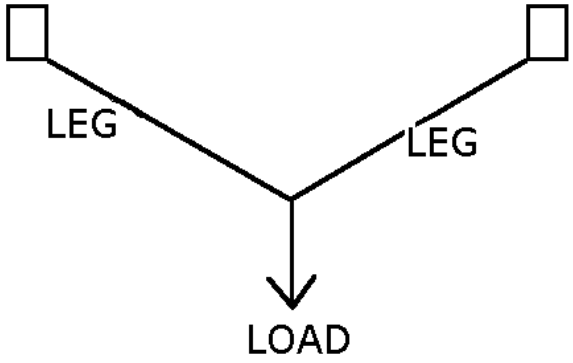
b) If he slides the brace over one cm closer to the corner so that it is attached at a point 15.5 cm to the right of the corner, will he clear the outlet?

Yes, but just barely. The brace will touch the wall at a point 16.3 cm from the corner.

Task Two: Determining Maximum Load

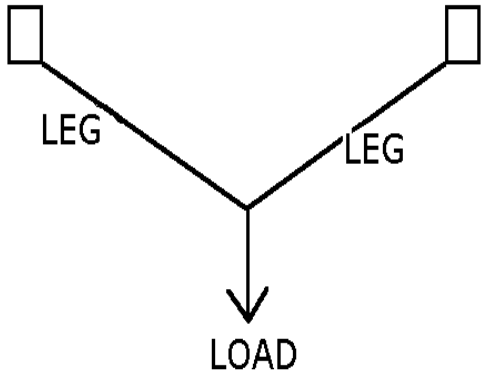
When Jack is working with steel, the job sometimes requires lifting heavy loads. If the load is lifted with one cable, it is said to be dead hung. Lifting the load with two cables from different hanging points is called bridling.

Two lengths of cable called legs are attached to a single shackle, and the load is attached to that.



Determining Maximum Load

With a bridle, the total load is divided between the legs of the bridle, but calculating the load placed on each leg is not that simple. There is a sideways pressure applied to the hanging points as the legs pull against each other as well as against the load, so you have to multiply the load by a number (shown in the table on the next screen) corresponding to the angle of the leg below horizontal to determine the actual load or tension on each leg.



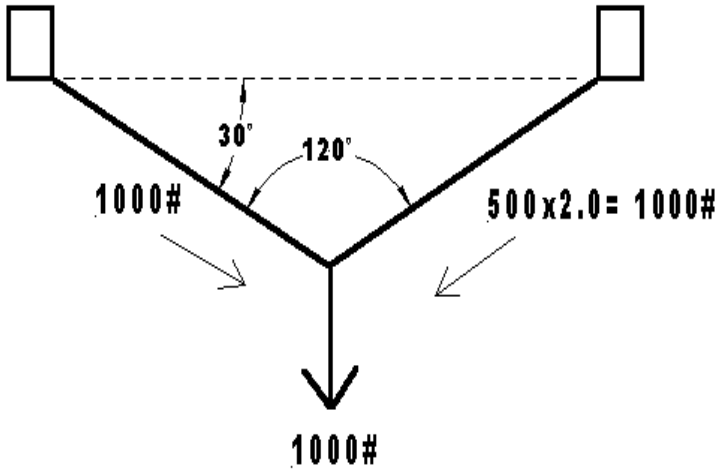
Table

Angle to Horizontal	Multiplier Factor	Angle to Horizontal	Multiplier Factor
10°	5.76	55°	1.22
15°	3.86	60°	1.15
20°	2.92	65°	1.10
25°	2.37	70°	1.064
30°	2.00	75°	1.035
35°	1.74	80°	1.015
40°	1.56	85°	1.004
45°	1.41	90°	1.00
50°	1.31		

Listen

Listen and follow along as Jack explains this example of determine the tension on each leg of a bridle. In the diagram the symbol # means pounds.

"A 1000 lb. load is hanging on two equal length bridles at an angle of 30° below horizontal. The load is divided equally between the legs.



This is called the vertical load. To find the vertical load on each leg you divide the actual load by the number of legs. So, for this example, the actual load is 1000 lbs and the number of legs is 2. The vertical load for each leg is 1000 ÷ 2 = 500 lbs.

Listen

However, the effective tension load on each leg of the bridle will be greater than its vertical load by the multiplier factor. So we need to multiply the vertical load of 500 lbs by a number we find in the previous table. This number is called the multiplier factor. For a 30° angle the table tells us the multiplier factor is 2.

So to find the actual load on each leg, we take the vertical load and multiply by the multiplier factor of 2. In this case: 500 lbs x 2 = 1,000 lbs. So the tension on each leg is 1,000 lbs.

Because a 30-degree angle was used, the tension on each leg was the same as the actual load. If we use a larger angle, the tension on each leg will be less, which will make the bridle more effective.

As a general rule, do not make a bridle with an angle to horizontal of less than 30°. The forces involved become great very quickly!

Steps

Here are the steps to determine the tension on each leg:

1) Divide the weight of the load by 2 or the number of legs.

2) Determine the Multiplier Factor by finding the angle from the horizontal and look up the corresponding number in the table.

3) Multiply the numbers from steps one and two. The answer is the amount of tension put on each leg.

Think About It!

If the horizontal angle on the same load is increased from 30 degrees to 40 degrees, will the tension on each leg be more or less?

The tension will be less.

Example

To find the tension on each leg when the angle is increased to 40 degrees, follow the steps outlined previously.

1) Divide the weight of the load by the number of legs, 2.

   1000 lbs / 2 legs = 500 lbs per leg

2) Determine the Multiplier Factor by finding the angle from the horizontal and looking up the corresponding number in the table.

   The angle is 40 degrees so the multiplier is 1.56.

3) Multiply the numbers from steps one and two. The answer is the amount of tension put on each leg.

   500 x 1.56 = 780 lbs

Example

Increasing the angle from 30 degrees to 40 degrees decreased the amount of tension put on each leg from 1000 lbs to 780 lbs.

What would the tension be if the angle were increased to 50 degrees for the same load?

1000 lbs/2 = 500 lbs, 500 lbs x 1.31 = 655 lbs

Practice

1) The weight of the load is 1,200 lbs and the angle of the leg from horizontal is 35 degrees.

1044 lbs

2) The angle of each leg from horizontal is 55 degrees and the load of the weight is 875 pounds.

534 lbs

Angle to Horizontal	Multiplier Factor	Angle to Horizontal	Multiplier Factor
10°	5.76	55°	1.22
15°	3.86	60°	1.15
20°	2.92	65°	1.10
25°	2.37	70°	1.064
30°	2.00	75°	1.035
35°	1.74	80°	1.015
40°	1.56	85°	1.004
45°	1.41	90°	1.00
50°	1.31		

3) The load weighs 1,525 pounds and the angle of the legs from horizontal is 65 degrees.

839 lbs

4) The angle of each leg from horizontal is 80 degrees and the weight of the load is 1,775 pounds.

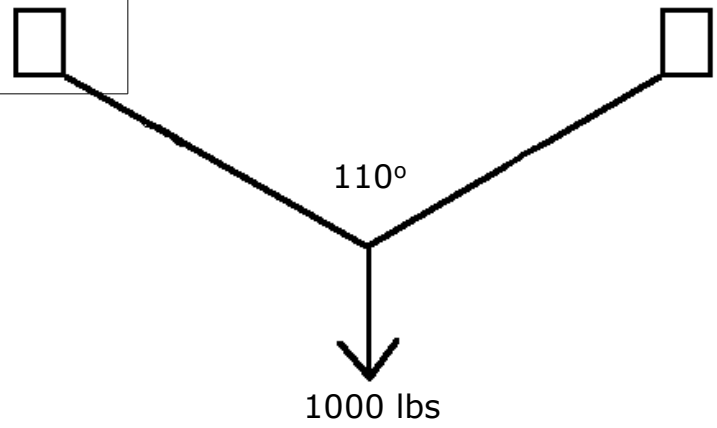
901 lbs

5) For a load that weighs 1,350 pounds what is the difference of the tension on each leg if the angle from horizontal is increased from 45 degrees to 60 degrees?

952 lbs – 776 lbs = 176 lbs

Determine Tension Using the Angle Between the Legs

Jack needs to determine the tension put on the legs of a bridle that he is using to lift a load of 1,000 lbs. He knows the angle the legs make with each other is 110 degrees.



Think About It!

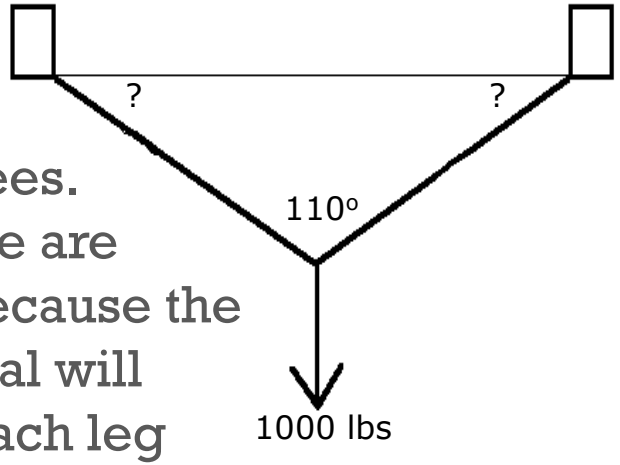
What piece of information does Jack need to determine the tension on each leg?

He needs to know the angle that each leg makes with horizontal.

Determine Tension Using the Angle Between the Legs

Jack knows there is a way to figure out the angle each the leg makes with horizontal. The first step is to draw a triangle:

The Triangle Sum Theorem says the sum of the angles in a triangle is 180°. This means for any triangle when you add the measures of all three angles you will always get 180 degrees.



In the triangle above we know one of the angles is 110 degrees. Since 180 – 110 = 70, the other two angles must add to be 70 degrees. Because the lengths of the legs of this triangle are equal, the triangle is an isosceles triangle. Because the triangle is isosceles, the angles with horizontal will be equal to each other. To find the angle of each leg with horizontal, divide 70 by 2. So each angle is 35 degrees.

Practice

F. Determine the angle of each leg with the horizontal. The angle given is the angle between the legs.

1) 150 degrees — 15 degrees

2) 60 degrees — 60 degrees

3) 90 degrees — 70 degrees

4) 40 degrees — 45 degrees

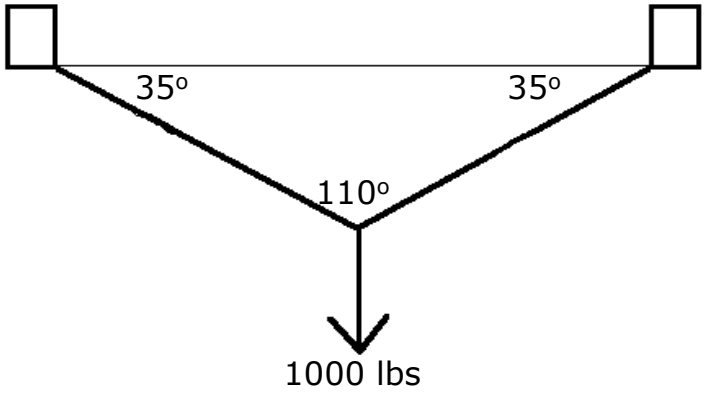
5) 110 degrees — 35 degrees

6) 10 degrees — 85 degrees

Example

Let's get back to the problem Jack is working on. We have determined that since the angle between the legs is 110 degrees, the other two angles would be 35 degrees.

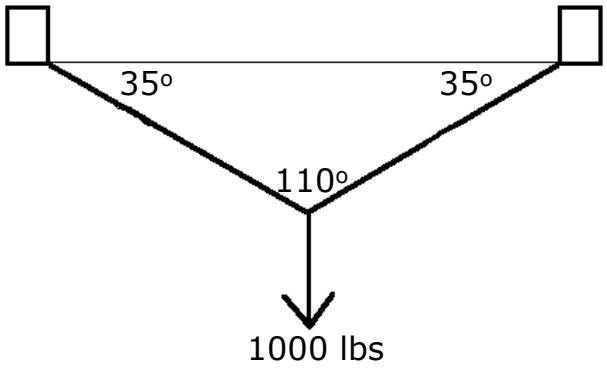
Now that we know the angle the legs form with horizontal is 35 degrees, we can determine the tension on each leg by dividing the load by 2 and then multiplying the result by the multiplier factor.



Example

What is the multiplier factor for this situation?

Look at the table for a 35 degree angle and the multiplier factor is 1.74



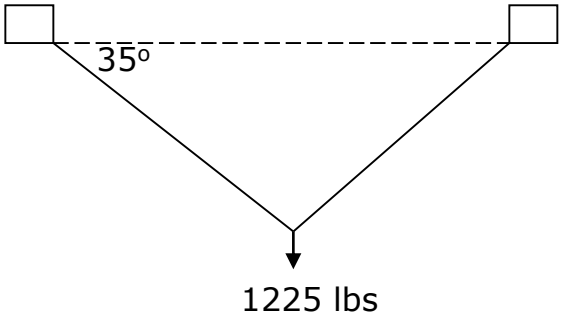
What is the tension on each leg?

1000/2 = 500 lbs, 500 lbs x 1.74 = 870 lbs

Practice

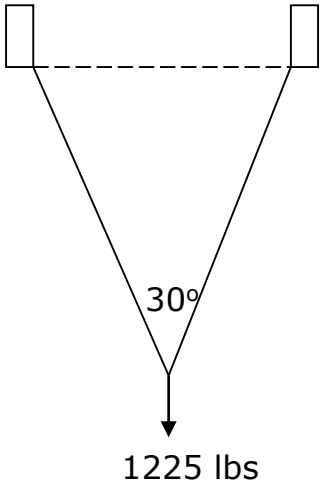
G. Find the tension on each leg. Round your answers to the nearest pound, if applicable.

1)



1066 lbs

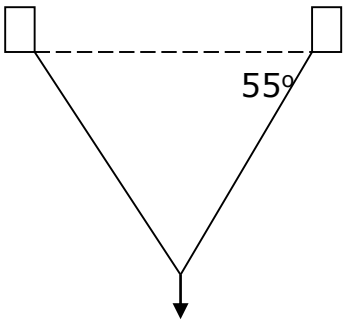
2)



634 lbs

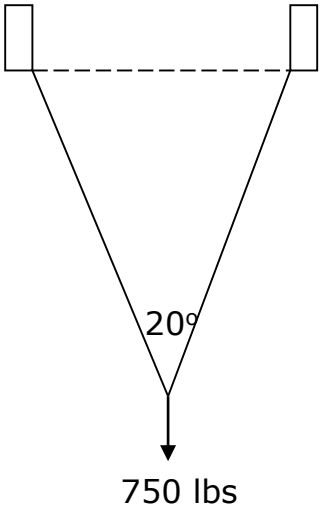
Practice

3)



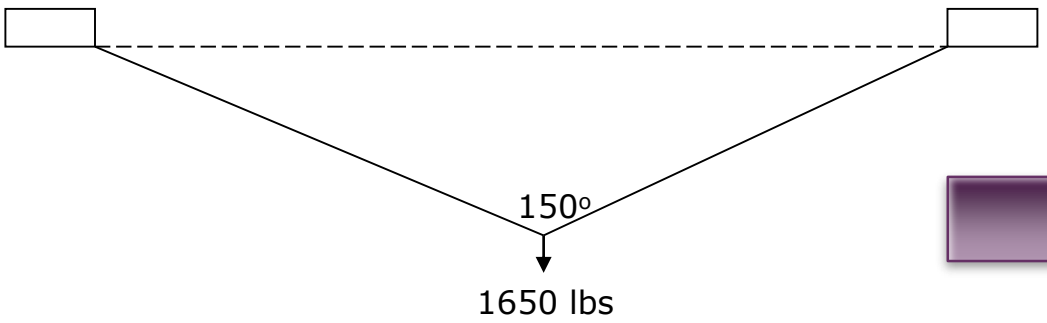
933 lbs

4)



381 lbs

Practice

5) 

3185 lbs

6) Which one of the five situations above is not an effective use of a bridle and why?

The bridle in #5 is not effective. By having an angle to horizontal that is less than 30 degrees, it actually creates more tension on each leg than if the load was lifted by that leg alone.

Putting It All Together

Now that you have completed this module you can:

- Use the Pythagorean Theorem to find any side of a right triangle as long as you know the other two sides.
- Determine the tension on each leg of a bridle.

Looks like you are ready for a quiz!

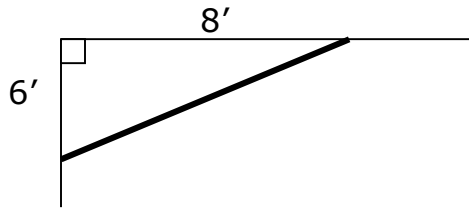
Quiz: Welding – Cutting Pipe to Length, Determining Tension

Part One: Answer the following computational questions. If needed, round your answers to the nearest tenth.

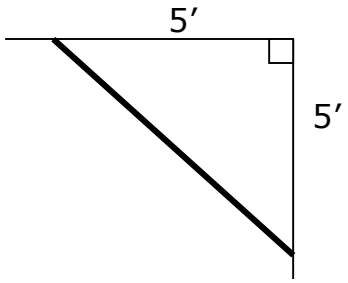
1) 4^2	16	5) $\sqrt{30}$	5.5
2) $(1.6)^2$	2.6	6) 5^3	125
3) $\sqrt{64}$	8	7) $\sqrt{144}$	12
4) $(3/4)^2$	9/16	8) $(1.25)^2 + 4^2$	17.6

Quiz

Part Two: Find the missing length in each triangle. Round your answers to the nearest tenth, if applicable.

9) 

10’

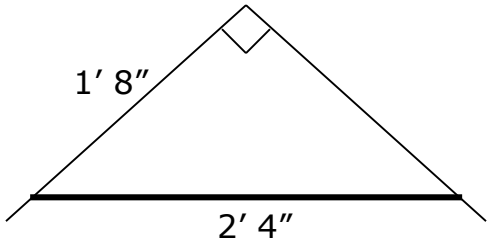
10) 

7.1 feet

Quiz

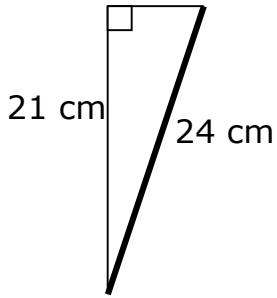
Part Two: Find the missing length in each triangle. Round your answers to the nearest tenth, if applicable.

11)



1′ 7.6″

12)



11.6 cm

Quiz

Part Three: Find the tension on each leg of the bridle.

13) The load is 1500 lbs and the angle of the legs to horizontal is 40 degrees. 1170 lbs

14) The load is 1350 lbs and the angle between the legs is 70 degrees. 823.5 lbs

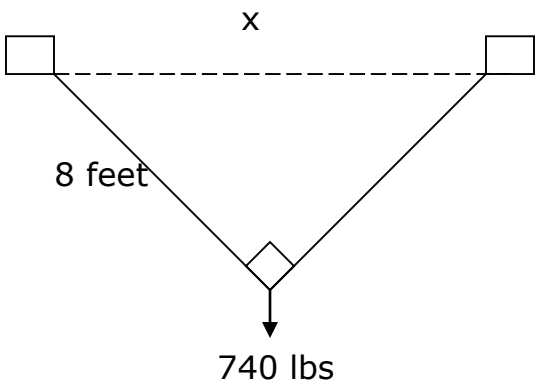
15) The load is three pieces of steel that each weight 380 lbs. The angle between the legs is 30 degrees.

589.95 lbs

Angle to Horizontal	Multiplier Factor	Angle to Horizontal	Multiplier Factor
10°	5.76	55°	1.22
15°	3.86	60°	1.15
20°	2.92	65°	1.10
25°	2.37	70°	1.064
30°	2.00	75°	1.035
35°	1.74	80°	1.015
40°	1.56	85°	1.004
45°	1.41	90°	1.00
50°	1.31		

Quiz

Part Four: Answer the questions about each situation. Round answers to the nearest tenth, if applicable.



a) What is the angle between the legs?

90 degrees

b) What is the angle of each leg with horizontal?

45 degrees

c) What is the distance between the hanging points of each leg (labeled x in the picture)?

11.3 feet

d) What is the tension on each leg of the bridle?

521.7 lbs

Prerequisites

- Multiply Decimals
- Multiply Fractions
- Rounding
- Converting feet and inches to just inches
- Converting basic fractions like ¼ and ½ to decimals

Key Math Concepts

- Working with Formulas
- Finding the Square Root
- Working with Angles
- Reading Tables
- Working with Triangles
- Problem Solving
- Working with Exponents
- Rounding
- Converting Units of Measure

Math Vocabulary

- Perpendicular
- Pythagorean Theorem
- Formula
- Sum
- Legs
- Right triangle
- Hypotenuse
- Exponent
- Base
- Equation
- Square root
- Whole number
- Infinite
- Irrational Number
- Squared
- Triangle Sum Theorem
- Angle
- Horizontal
- Vertical
- Multiplier factor
- Isosceles triangle

Congratulations!

You have completed the Math Module.

The end