Engineering GatorTRAX

Civil Engineering Module: Bridges
Introductory Level

Designed in accordance with Tau Beta Pi MindSET standards
by ***Florida Engineering Society, 2009***

STUDENT COPY

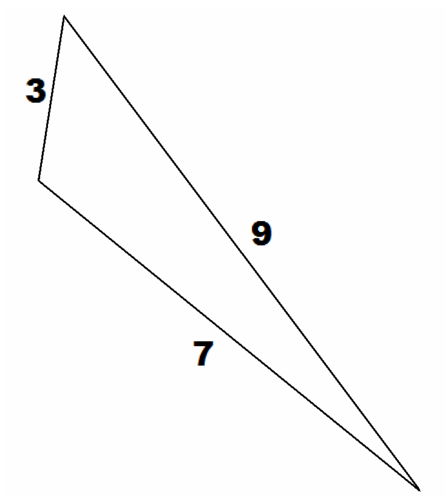
ENGINEERING GATORTRAX MATH EXCELLENCE PROJECT
ENGINEER-FOR-A-DAY LABORATORY MODULES
CIVIL ENGINEERING: BRIDGES
INTRODUCTORY LEVEL

Classroom Activity:

Section 1.1: Triangles

Triangles are the strongest shape you can use to build a bridge. Every triangle has three sides, and we know that if you add the lengths of the two shortest sides of a triangle, that number must be greater than the length of the longest side.

Example:



If you add up the sides of the triangle, you get:

$3 + 7 = 10$

The length of the longest side is 9, so this works! If the length of the longest side were 10 or 11, the sum of the two shortest sides would not be greater than the length of the longest side, and we would not have a triangle.

Experiment:

Using straws, try to make triangles with the side lengths below. Which ones make triangles? Which ones don't?

	Side 1	Side 2	Side 3	Does it make a triangle?
Triangle 1:	1 straw	1 straw	1 straw	______________________
Triangle 2:	1 straw	2 straws	1 straw	______________________
Triangle 3:	1 straw	2 straws	4 straws	______________________
Triangle 4:	1 straw	2 straws	3 straws	______________________

Why couldn't you make triangles 3 and 4?

____

____

____

____

____

Now you see! If the two shortest sides don't add up to be longer than the longest side, then you cannot make a triangle!

Section 1.2: Inequalities

If you know how long two of the sides of a triangle are, how do you know how long to make the third side? For this problem, we use something called **inequalities**.

> ‘<’ means *less than*.
> For example:
> $4 < 7$ means *“4 is less than 7”*
>
> ‘>’ means *greater than*.
> For example:
> $5 > 3$ means *“5 is greater than 3”*

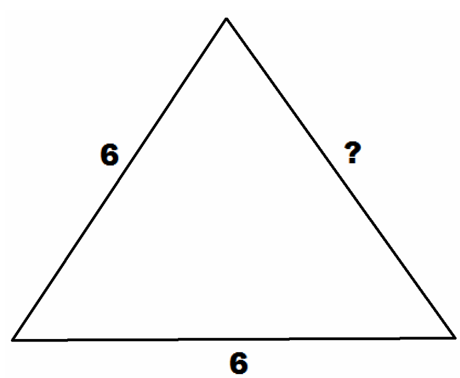
<u>CHALLENGE: Try a few of these on your own to make sure you understand!</u>

Fill in the circles:

5 (>) 4	3 ◯ 1	3 ◯ 4
2 ◯ 8	7 ◯ 5	9 ◯ 6

So what about triangles? If you know how long the first two sides are, then you know that if you add up their lengths, that number must be *greater than* the length of the third side.

For example:



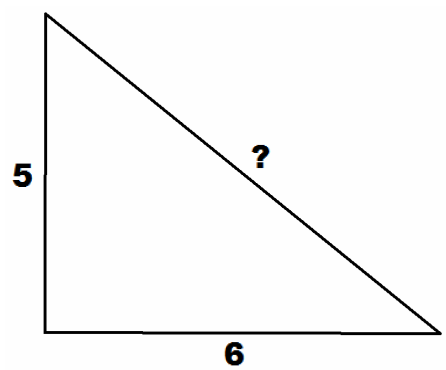
How long does the third side need to be to make a triangle? Since the two other sides add up to $6 + 6 = 12$, we know that 12 must be *greater than* the length of the third side! Another way to say this is that the third side must be *less than* 12.
In math terms, this is:

$$6 + 6 > ? \qquad \text{or} \qquad ? < 6 + 6$$

Since $6 + 6 = 12$, you can simplify too!

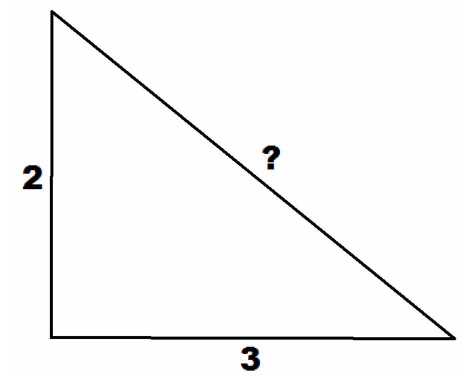
$$12 > ? \qquad \text{or} \qquad ? < 12$$

CHALLENGE: Try filling in the circles yourself!



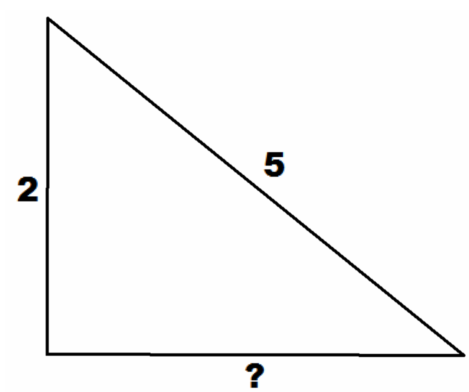
Example: **5 + 6 > ?**

6 > ?



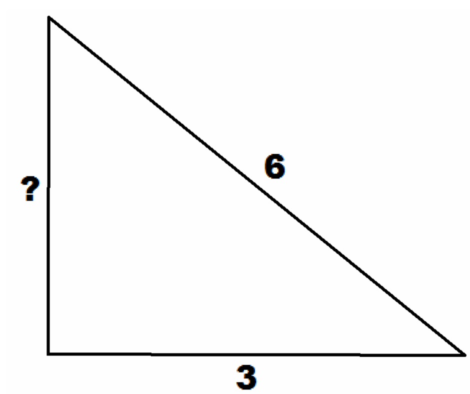
____ + ____ ○ ____

____ ○ ____



____ + ____ ○ ____

____ ○ ____



____ + ____ ○ ____

____ ○ ____

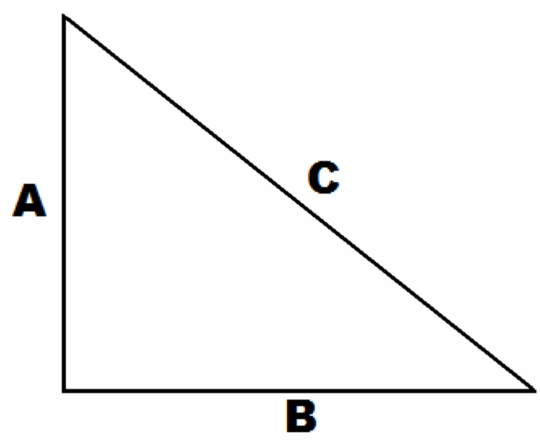
Experiment:
For each of the four triangles above, estimate a length for the third side that would make a triangle. Then, use straws to make each triangle.

	Side 1	**Side 2**	**Side 3**	**Did it make a triangle?**
Triangle 1:	5 straws	6 straws	________	________________
Triangle 2:	2 straws	3 straws	________	________________
Triangle 3:	2 straws	________	5 straws	________________
Triangle 4:	________	6 straws	6 straws	________________

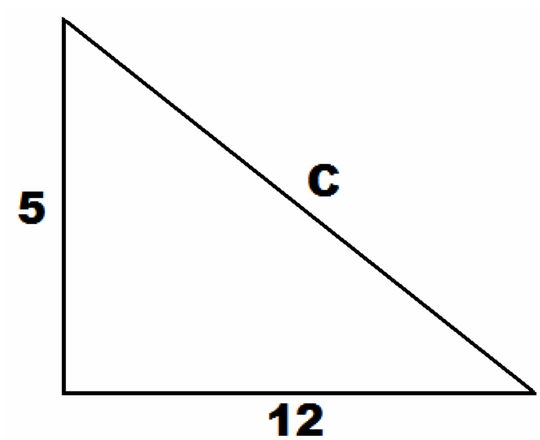
Section 1.3: Pythagorean Theorem

If one of the angles of a triangle is 90°, then the triangle is known as a **right triangle**. And if a triangle is a right triangle, then you can use the **Pythagorean Theorem** to find the length of the third side exactly.

Pythagorean Theorem: $A^2 + B^2 = C^2$
where A. B. and C are the lengths of the sides of the right triangle.



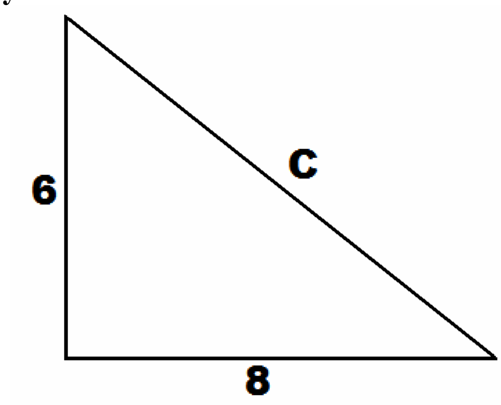
Example:



We know: $A = 5$ $B = 12$
$A^2 = 5 \times 5 = 25$ $B^2 = 12 \times 12 = 144$

So $C^2 = A^2 + B^2 = 25 + 144$
$C^2 = 169$
$\mathbf{C = 13}$

CHALLENGE: Now you try!



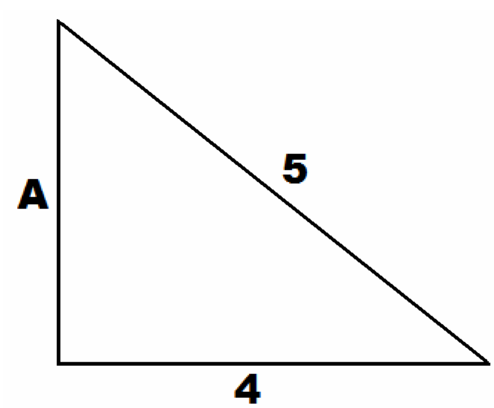
A = __________ B = ___________

A^2 = ___ x ____ = _________ B^2 = ___ x ____ = _________

$A^2 + B^2$ = _____ + _____ = _______ = C^2

C = ____________

This next one is a little different. Now you know C and you have to figure out A. Since you already know $A^2 + B^2 = C^2$, you also know that $C^2 – B^2 = A^2$. Good luck!



B = __________ C = ___________

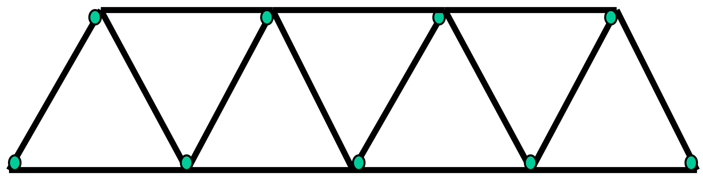
B^2 = ___ x ____ = _________ C^2 = ___ x ____ = _________

$C^2 - B^2$ = _____ — _____ = _______ = A^2

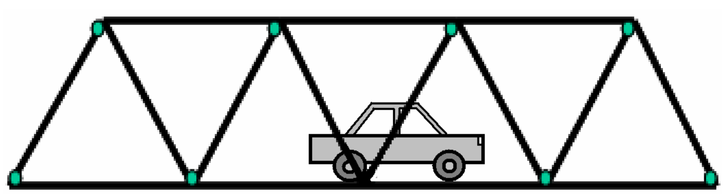
A = ____________

Section 1.4: Triangles in bridges

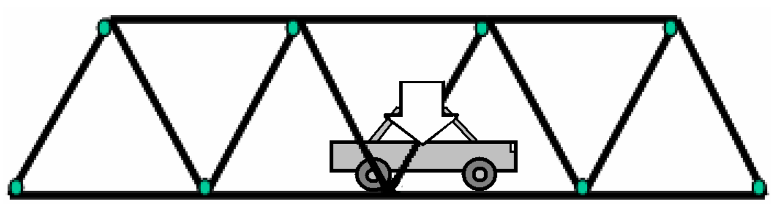
A triangle is the shape that makes up most bridges. Planks of wood or metal beams can be assembled together into triangles, like they are below.



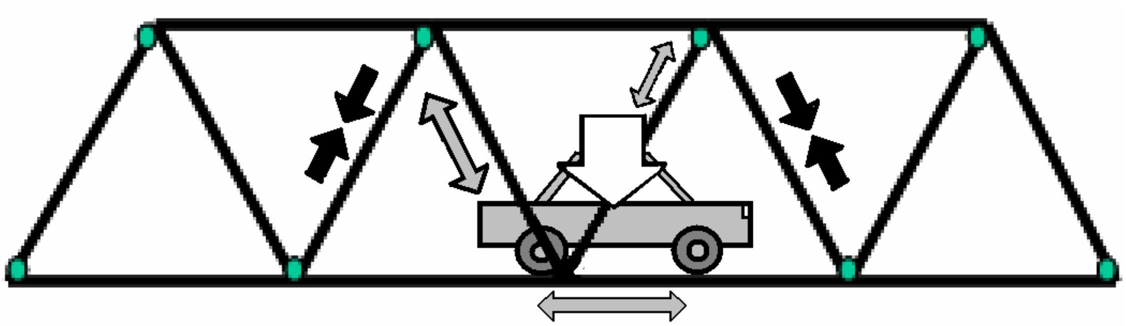
Eventually, all these triangles form a bridge! Your bridge must be designed so that it is strong enough to support a lot of weight, such as a car.



When the car drives along the bridge, its weight creates a **force** pushing down on the bridge.



A force that pulls things apart is called **tension**. A force that pushes things together is called **compression**. Triangles work so well because they take the force from the car and distribute it as tension and compression all over the bridge! In the picture below, the gray arrows are tension forces, and the black arrows are compression forces.



Section 1.5: Measuring force and unit conversions

Force can be a lot of different things, such as tension and compression. One of the most common kinds of forces is your **weight**. You probably measure yourself in pounds (lbs), but other common units of force are the Newton (N) and the ton. Units of mass, such as the gram (g) and the kilogram (kg) can also be used as units of weight as long as we are on planet Earth (weight changes depending on whether you are on planet Earth or in the gravitational field of another planet, but mass stays the same).
On Earth, then, the conversions between these units are:

1 lb	=	.0005 ton	=	4.45 N	=	.454 kg	=	454 g
2000 lb	=	1 ton	=	8900 N	=	908 kg	=	908000 g
.225 lb	=	.000113 ton	=	1 N	=	.102 kg	=	102 g
2.20 lb	=	.0011 ton	=	9.81 N	=	1 kg	=	1000 g
.00220 lb	=	.0000011 ton	=	.00981 N	=	.001 kg	=	1 g

Another common unit needing to be converted is **length**. You probably measure length in feet (ft), but other units that are used in engineering include inches (in), centimeters (cm), and meters (m).

1 ft	=	12 in.	=	30.48 cm	=	.3048 m
.083 ft	=	1 in.	=	2.54 cm	=	.0254 m
.0328 ft	=	.394 in.	=	1 cm	=	.01 m
3.28 ft	=	39.4 in.	=	100 cm	=	1 m

CHALLENGE: Solve the following problems!

1. The Ford Taurus, one of the most common cars on the road today, weighs 3326 lbs. How much is that in tons?

2. The Golden Gate Bridge weighs 894,500 tons. How much is this in Newtons?

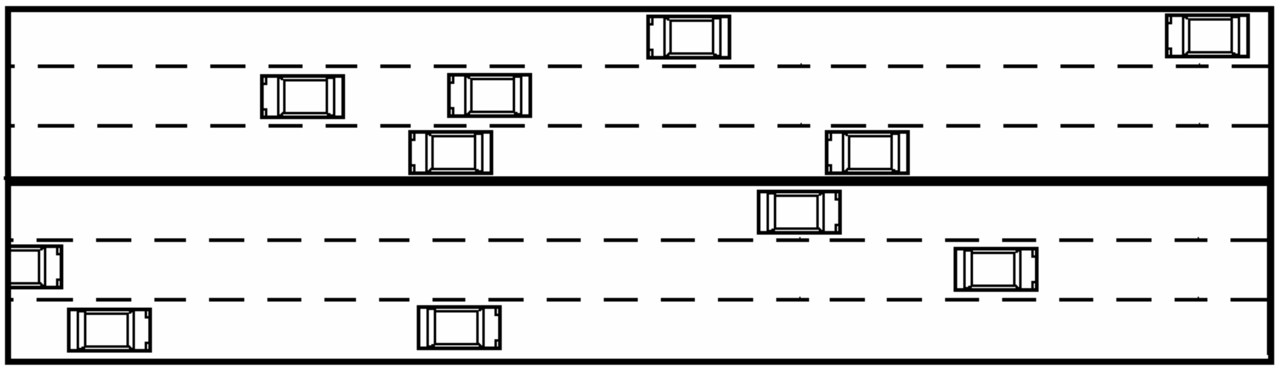
3. A typical person weighs 75 kg. How much is that in pounds?

4. The Sunshine Skyway is 8851 m long. How long is that in feet?

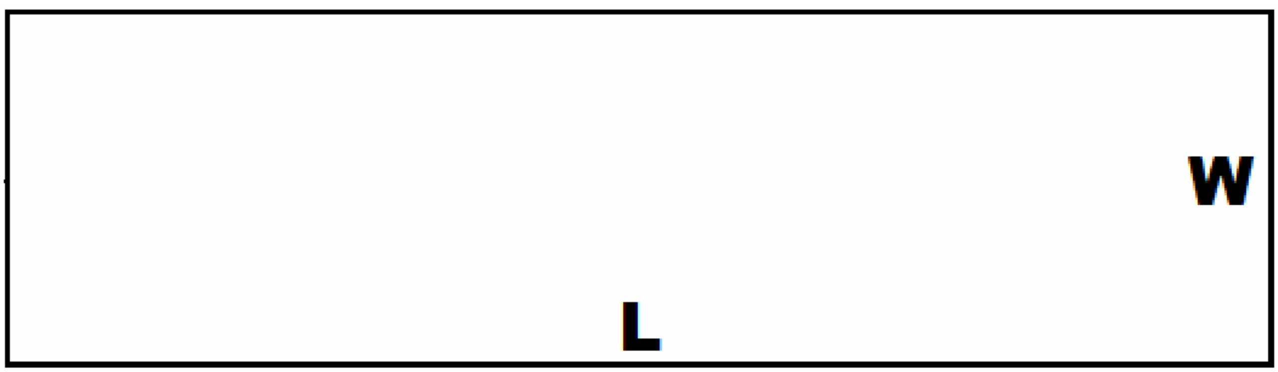
5. The bridges you build will need to be no more than 2 ft long. How long is that in inches? In centimeters?

Section 1.7: Geometry and Estimation

What if you want to estimate how many cars will fit on your bridge? If you look at it from above, your bridge looks very busy, with 6 lanes, a barrier in the middle, and cars everywhere.



However, a bridge is really just a rectangle with width W and length L.



If you want to estimate how many cars will fit on the bridge, all you need to know is the area of the bridge and the area of a car.

For the bridge: A = L x W

Cars can be treated as rectangles too! For a car of width *w* and length *l*, its area is:

a = *l* x *w*

Example:

A typical car has l = 5m and w = 1.8m. If you have a small bridge with L = 25m and W = 8m, about how many cars can you fit on your bridge?

Answer: For the bridge: $A = L \times W = 25m \times 8m = 200\ m^2$

For the car: $a = l \times w = 5m \times 1.8m = 9m^2$

Now, all you have to do is divide A by a to get your answer!

Number of cars $= \frac{A}{a} = \frac{200m^2}{9m^2} = 22.2 \approx$ **<u>22 cars</u>**

<u>CHALLENGE: Now you give it a try!</u>

Question: The Golden Gate Bridge is 6,450 ft long and 90 ft wide. If cars are the same size as in the example above, about how many cars can fit on the Golden Gate Bridge?
HINT: You must convert the length and width of the bridge to meters first.

<u>Think like an engineer:</u> Name some ways that you could make your estimate more accurate:

Possible answers: 1) Account for space in between cars. 2) Estimate the number of lanes from the given width of the bridge, and then just use the length of the bridge to determine how many cars will fit. 3) Account for the sizes and approximate frequency of different kinds of cars.

Section 1.8.1: Efficiency

To be a good engineer, you have to build an efficient bridge. What this means is that your bridge must weigh as little as possible while still supporting as much weight as possible.

If L is the maximum load (weight) that your bridge can support, and W is the weight of your bridge, then we can define the **efficiency factor** of your bridge as:

$$\eta = \frac{L}{W} \times 100\%$$

Example: Katie's bridge weighed .8 kg and supported a 7 kg load. What was the efficiency factor of her bridge?

Answer: The question tells us that W = .8 kg, and L = 7 kg. So we can plug these into our equation:

$$\eta = \frac{L}{W} \times 100\% = \frac{7kg}{.8kg} \times 100\% = 8.75 \times 100\% = \mathbf{875\%}$$

Section 1.8.2: Cost

The next problem to consider is **cost**. Engineers have to work on a budget, so it is important not to spend more money than we need to. If each part of a bridge costs a certain amount of money, then it is important to try and use as few parts as possible.

Example:

Reggie is asked to build a bridge out of straws and paperclips. Each straw costs $1, and each paperclip costs $2. If Reggie's bridge used 10 straws and 6 paperclips, how much did his bridge cost?

Answer: Cost = 10 straws + 6 paperclips = 10 x $1 + 6 x $2 = $10 + $12 = **$22**

Reggie's bridge cost $22 to build!

Section 1.8.2 Cost and efficiency

CHALLENGE:

Percy and Maria are competing against each other in a bridge-building competition. They are each allowed to use as many popsicle sticks, paperclips, and gumdrops as they wish, but each comes at a price:

Popsicle stick	$1
Paperclip	$3
Gumdrop	$5

The data from each of their bridges is below. Whose bridge had the better efficiency (η)? Whose bridge was more cost-effective?

	Percy's bridge	Maria's bridge
# of popsicle sticks	18	17
# of paperclips	8	13
# of gumdrops	3	4
Weight (*W*), in kg	.48	.59
Load (*L*), in kg	3.4	4.3
Efficiency (η)		
Cost ($)		

Based on what you calculated, who do you think deserves first place? Why?

____
____
____
____
____
____

CONGRATULATIONS! You've finished the classroom activity and are ready to begin building your bridge!