STRUCTURES

Worksheet 1

A worksheet produced by the Native Access to Engineering Programme

What is a structure?

> *According to Webster's Dictionary a structure is:*
> *an arrangement of parts, elements, or constituents; something made up of a number of parts held or put together in a specific way.*

Think of a structure as a combination of parts which work together to...

...hold something up (a TV stand, a tree);

...enclose a space (a house, a cave);

...connect two points (a bridge, an elevator);

...hold back natural forces (a dam, a canoe).

Structures can also be artistic, decorative or symbolic.

Structures can be immensely large like the CN Tower

The CN Tower is 553 m high. It is the tallest free-standing structure in the world.
It is designed to withstand winds up to 420 km/h.
The tower weighs 118,000 tonnes.

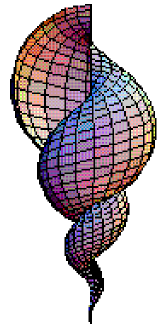
or microscopically small like DNA, the basic structure of life.

An actual strand of DNA would have to be magnified about a million times to appear as big as the picture.
The structure of DNA is called a double helix.
The Human Genome Project is trying to decode - essentially take apart - the structure of DNA piece by piece.

Structures can be both natural and made by people.

Natural Structures

beaver dam
tree
bee hive
human body
spider web
nest

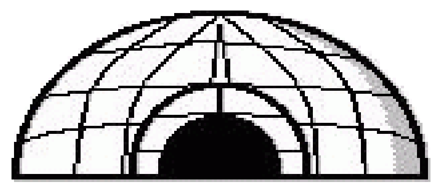


Structures made by people

buildings
bridges
dams
towers
roads
bicycle frames

Structures made by people are usually designed by civil engineers. Many of the structures which Aboriginal peoples have traditionally and historically designed are excellent examples of civil engineering.

Longhouse
Igloo
Canoe
Snowshoes
Navajo irrigation systems
Totem poles
Aztec pyramids



What structures are traditional in your community?

Loads

When people and nature design structures it is very important that the structures are strong enough to withstand the loads which will act on them.

Loads are forces which act on a structure.

There are two types of loads.

Static loads: These loads remain constant (the same) over time. Static loads include the force caused by the weight of the structure itself as well as the forces caused by the weight of objects placed in or on the structure. A sculpture sitting a floor is a static load.

Dynamic loads: These loads are caused by forces which move across a structure or cause a structure to move. Cars moving across a bridge are a dynamic load. Earthquakes are dynamic loads.

Can a load be both static and dynamic?
Yes, but not at the same time. Snow falling on a roof is a dynamic load while it is falling, but as soon as it stops it becomes a static load on the roof.

Example:

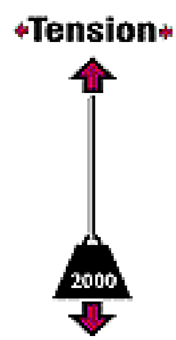
Think about the structure of a tree. It is subject to a lot of loads throughout the year. What static and dynamic loads work on it?

...squirrels running across the branches.
...nests and beehives.
...wind.
...snow falling on its branches.
...snow sitting on its branches.
...the weight of the tree, its branches and its leaves.

What other loads act on trees?

Tension and Compression

Tension is the force caused by a load which which pulls on a structure. When parts of a structure are under tension the material they are made of tries to get longer. When you pull on a rubber band it is in tension. The reins on dogs pulling a sled are also in tension. What other structures (or parts of structures)can you think of that are in tension?



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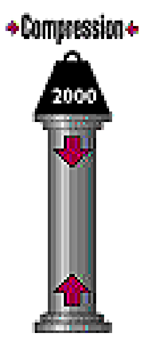

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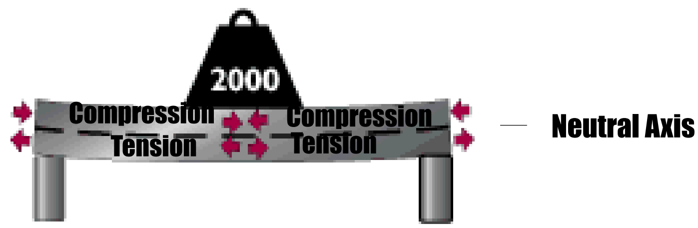
Compression is the force caused by a load that pushes on a structure. When parts of a structure are in compression the material they are made of tries to get shorter. If you squish a piece of foam it is in compression. What other structures (or parts of structures) can you think of that are in compression?

A load placed on a straight beam will cause the beam to deform. The top of the beam is in compression and gets shorter. The bottom of the beam is in tension and gets longer. The line right along the middle of the beam stays exactly the same length. It is called the neutral axis because it not subject to any forces from the load.



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Astronauts who spend a lot of time in space can grow up to 2 1/2 inches. Can you figure out why?

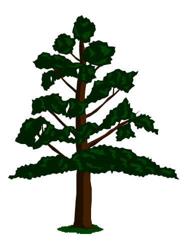
What does it mean to withstand a load?

Structures withstand loads if they can support all the forces acting on them without collapsing or breaking.

What happens if you stand on thin ice? It begins to crack and eventually breaks so that you fall into the water. When this happens it is because the structure of thin ice is not strong enough to support the load on it - you.

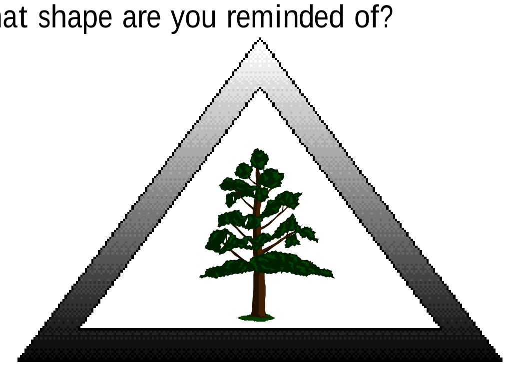
So how do you make sure structures are strong enough?
There are several ways to give structures the strength to withstand the loads. One of the best places to look for strong structures is to look at nature.

Look at the tree.



Look at a Mayan pyramid.

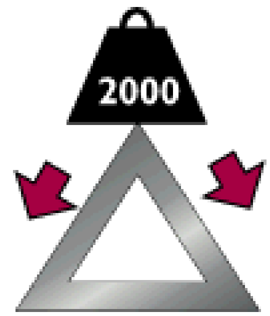
What shape are you reminded of?



The importance of shapes

The triangle is a very strong structure. Why? Well look at a square. Squares tend to deform into parallelograms under heavy loads. If you insert a member along the diagonal of the square (this is called inserting cross-bracing) you create two triangles and the square will no longer deform.

Triangles are able to transfer their loads into the ground very easily. Even if you are walking on the tenth floor of a 20 storey building what is ultimately holding you up is the ground. You are supported by the floor which is supported by the walls which are supported by the ground. The surface of the Earth holds up every person, animal, insect, plant, building, car, truck, mountain, ocean etc. that is on it.



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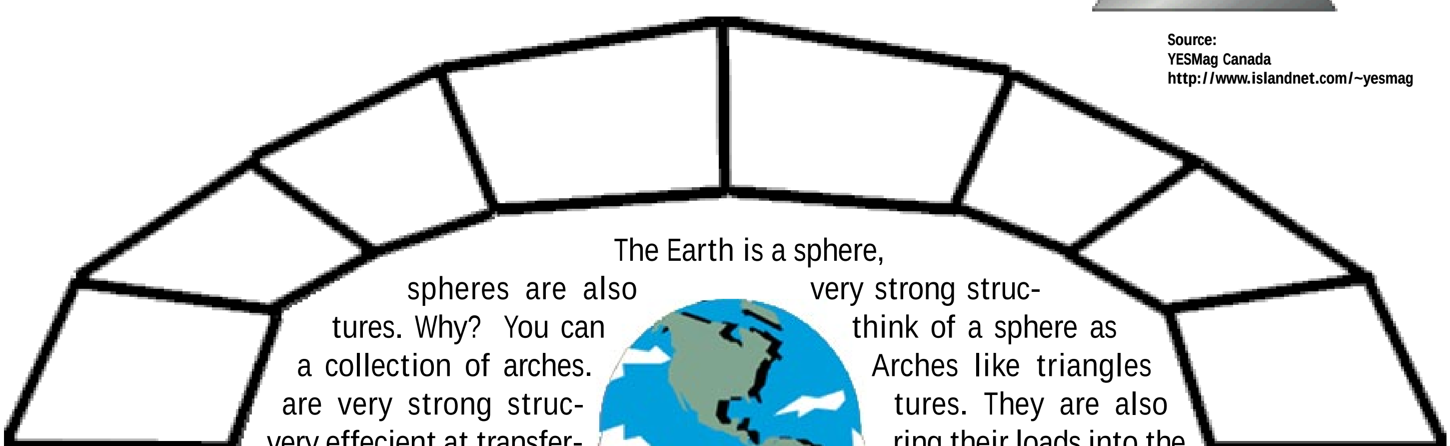


The Earth is a sphere, spheres are also very strong structures. Why? You can think of a sphere as a collection of arches. Arches like triangles are very strong structures. They are also very effecient at transferring their loads into the ground. Native designers have known about the strength of arches for a long time. Can you think of what they built using arches?

References

Books

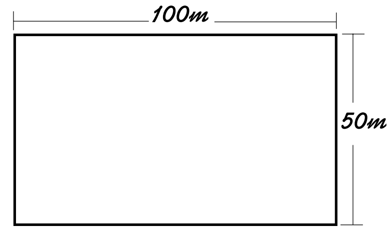
Gradwell, John, Malcolm Welch and Eugene Martin. *Technology: Shaping Our World*, 1993, (Goodheart Willcox Company, Inc., Illinois)

Online

1. **Factoids**
   http://www.gene.com.ae/WN/Factoids
2. **Native SchoolNet**
   http://www.schoolnet.ca/ext/ext/aboriginal
3. **YESMag Canada**
   http://www.islandnet.com/~yesmag

Math Problems

1. You are the project manager for the new ice rink being built in your community. The building will be 100m long by 50m wide. All of the weight of the roof will be supported by wood columns which form the outside structure of the arena. The roof weighs 1000 metric tons. Each winter you can expect 100 metric tons of snow to fall on the roof.

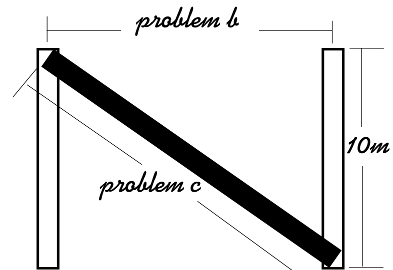


Top view of ice rink

a) Each column supports 30 metric tons. For aesthetic purposes, there must be an even number of columns. How many columns do you need to support the roof?

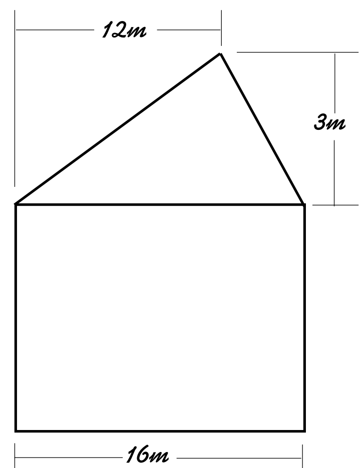
b) The columns should be spaced evenly around the building. How far apart should you place them (to the nearest centimeter)?

c) The columns are each 10m high. To make your building more stable you want to insert cross brace beams in the wall between each column. How long should each of these beams be? You are looking for the length of the shaded beam in the figure at right.



Section view of wall

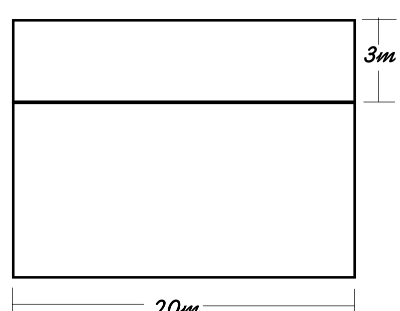
2. You have opened a local roofing company. A client has asked you to build a new roof for her business. The client wants to install a skylight. One side of the roof will have to be steeper than the other so that in the winter snow slides off the roof instead of building up against the skylight. The first thing you must do is build the roof trusses (the triangular supports for the roof).



Side view of building

a) Your client's building is 16m deep. The peak of the roof is 12m from the front of the building. The roof is 3m high. How long should each member of the truss be? (Hint:This is the same as finding the length of each leg of a triangle.)

b) The front of the building is 20m wide. You must place your trusses every 1.5m. How many trusses do you need to complete the project?



Front view of building

c) You call the local wood supplier to provide the members for the trusses. The supplier cuts pieces from 30m members. You need to tell him how many beams of each length you need. The supplier charges per member and per cut. How many 30m members will you have to purchase. What is the least number of cuts you will pay for? How much wood will be left over?(Hint: There is more than one way to solve this problem. An engineer would try to make both the cost and the amount of left over wood as low as possible.)