# Engineering GatorTRAX

## Structural Engineering Module
## Intermediate Level

*Designed in accordance with Tau Beta Pi MindSET standards*
*By* ***American Society of Civil Engineers, University of Florida Chapter, 2009***

**Forces**

Definition: a force is that which can cause an object with mass to accelerate. Forces have both magnitude and direction.

Newton's Second Law: F=m*a where F is the force measured in pounds (lb) or Newtons (N), m is the mass measured in kilograms (kg) or slugs, and a is the acceleration measured in feet per second squared or meters per second squared

English Units: lb= slugs*ft/$s^2$
Metric Units: N= kg*m/ $s^2$

Example Questions:

1) Kyle pushes on a box that has a mass of 50 kg. It moves with an acceleration of 1.2 meters per second squared. What is the force that Kyle is exerting on the box?

2) Caitlin has a wheelbarrow and she wants to fill it with dirt and accelerate it at 4.7 ft/$s^2$ to an area where she will plant flowers. She is only able to apply 120 pounds of force to the wheelbarrow. How much dirt should she put in the wheelbarrow to make sure she can do this?

3) Benjamin throws a baseball that has a mass of 1.9 kg with a force of 202 Newtons. How fast will the baseball accelerate?

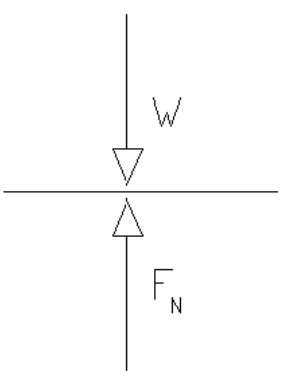
**Normal Force**

Newton's Third Law: F= -F

normal is a fancy word for perpendicular. The normal force is often denoted by the symbol $F_n$. Anytime you exert a force on something, the object pushes back on you with an equal and opposite force.

Weight: W=m*g

Notice the similarities between F=m*a and W=m*g. Weight is a special type of force. It is the gravitational force acting on an object. The acceleration due to gravity is used to measure weight and it is fairly constant at 9.81 m/$s^2$ or 32.2 ft/$s^2$.



Stand on a scale and read the value. It pushes back normal to the plane you are standing on (the surface of the scale) with that value. You can feel the force on your feet.

Example Questions:

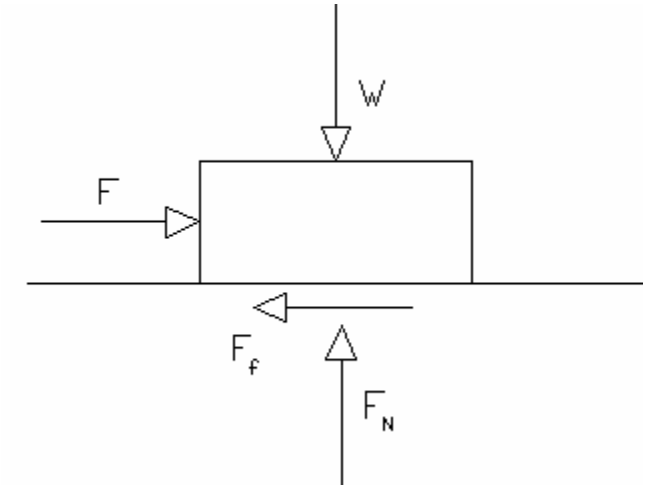
1) David has a mass of 4.3 slugs. How much does he weigh?

2) Heather weighs 5.33 Newtons. What is her mass?

3) Kevin and Jody are standing on a dock watching the sunset. Kevin weighs 121 lbs and Jody weighs 192 lbs. What is the normal force exerted by the dock.

**Friction Forces**

Definition: friction forces act in the opposite direction to the object's movement. Smooth surfaces have less friction than rough surfaces. It is easier to ride your bike on the street than in the grass.



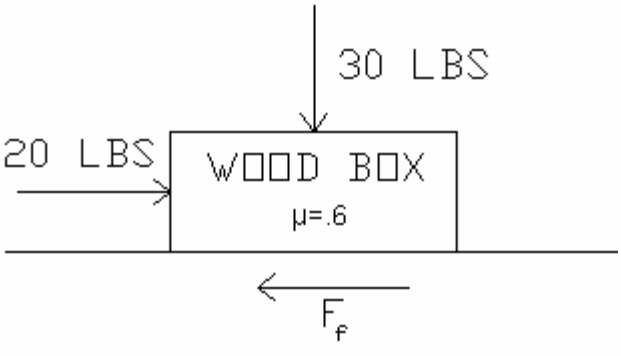

$F_f \leq \mu * F_N$ where $F_f$ is the friction force, $\mu$ is the coefficient of friction, and $F_N$ is the normal force between the surfaces. $\mu$ has no units. You will often see this value as $\mu_s$ for the coefficient of static friction which means the object has not begun to move yet even though there is a force being exerted on it. You may also see this value as $\mu_k$ for the coefficient of kinetic friction which means the object has begun to move.

When an object is rolling it is always due to static friction even though it is moving because the object only has a point contact for a split second. The tires on your bike have static friction with the road. They touch the road, but never slide or slip against it.

Kinetic friction implies something is sliding. For example, if you are moon walking, your shoes slide against the dance floor so there is kinetic friction between the shoes and the floor.

The friction force can never be greater than the force it is opposing. If it was somehow greater, then the object would be moving towards the force pushing it. This could never happen.

Example Questions:




1) Find Ff in the figure above.

2) If the friction force on a block of Aluminum is 30 Newtons, what is the normal force on the block? ($\mu_s$ = .61)

**Moments**

Definition: a force that causes rotation around a pivot point. A moment is positive if it causes a counterclockwise rotation and negative is it causes clockwise rotation.

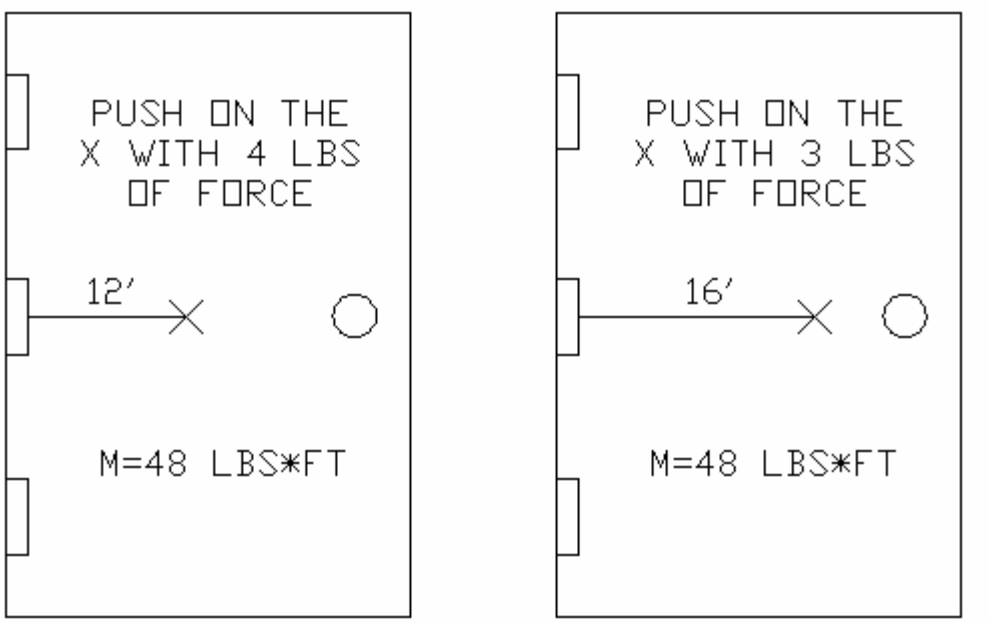
Moment Arm: the distance from the pivot point to the place where the force is exerted on the object.

$$M=r*F$$

M is the moment (lbs*ft or N*m), r is the moment arm (ft or meters), F is the force applied (lbs or Newtons)

*Note: r and F are perpendicular to each other.

Push on a door near the hinge and then try to push on it near the door knob. Notice that it is harder to move the door when you push near the hinge. This is because the moment arm is shorter near the hinge so you have to push harder to produce the same moment you get from pushing near the door knob.




The door requires the same moment to be moved no matter what, but by pushing further from the hinge you can exert a smaller force and it is easier for you to move it.

Example Questions:

1) Michael Phelps stands at the edge of a 7 ft long diving board. He weights 176 lbs. What is the moment at the edge of the board?

2) A red bird that weighs .6 lbs is perched on a branch. The bird is causing a moment of 19.2 lbs*in in the branch. How far from the tree trunk is the bird standing?

3) Justin is swinging on a tire swing at a playground. The swing requires a moment of 56 lbs*ft to move with Justin on it. Jason comes over to give Justin a push. If the distance from the branch where the swing is tied down to the point where Jason is pushing is 17 ft, how much force does Jason have to use to make Justin move on the swing?

**Stress**

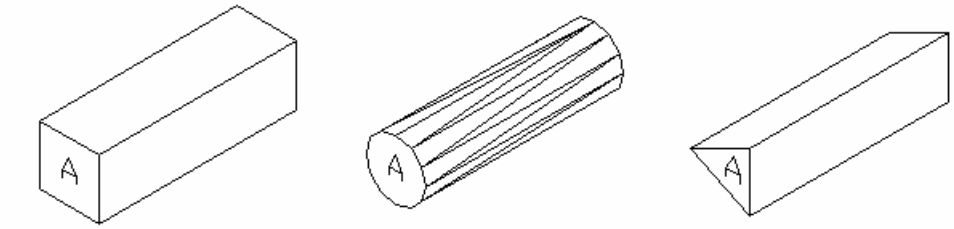
Compressive Stress: when a force is applied to some material that causes it to shorten or become compact the object is under compression. Concrete is good at handling compressive forces. Compression is often represented as a negative value.

Tensile Stress: when a force is applied to some material that causes it to stretch or become longer and more slender, the object is in tension. Steel is good at handling tensile forces. Rope and string can only be in tension (never in compression). Tension is often represented as a positive value.


Stress = force/area $\sigma = F/A$ units: $lbs/in^2$ or $N/m^2$

The area in this equation is the area of the cross section of a piece of material. The cross section is what you see when you cut the material.

For example, the cross sectional area of the middle figure below is $pi*r^2$ where r is the radius of the circle and pi is an irrational constant that we often round to 3.14.




A Chinese finger trap becomes longer and thinner when you put your fingers in it and pull. The finger trap is in tension. When you push in on the finger trap it becomes shorter and fatter. The finger trap is in compression. The openings get bigger so you can get your fingers free.

Example Questions:
1) A dog is tied to a tree with a chain. It sees a squirrel and pulls the chain tight with a force of 92 lbs as he tries to run after the squirrel. The cross sectional area of the chain is 2 $in^2$. What is the stress in the chain? Is it tensile or compressive?

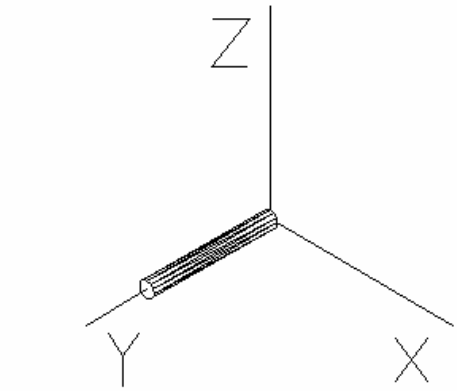
2) Scott makes a concrete mix and tests it by braking concrete cylinders. He has designed the mix to have a strength of 4500 $lbs/ in^2$. The cylinders break when the force is at 15750 lbs. What is the cross sectional area of the concrete cylinders?

**Inertia**
Moment of Inertia: an object's *resistance* to changes in its rotation rate. The moment of inertia changes when you rotate the object around different axes.

$$I=MR^2$$

M = mass, R = distance from the center of mass of the object to the axis it is rotating around, I = moment of inertia

Center of Mass: the point in an object where it can be balanced. For example, a seesaw has a center of mass right in the middle. You can balance the seesaw because it has a pivot point right at the center of mass.




When talking about the moment of inertia, you have to specify which axis you are talking about. It doesn't make sense to say "What is the moment of inertia of the cylinder?" It does make sense to say "What is the moment of inertia of the cylinder about the Y axis?"

The cylinder in the figure above has a smaller moment of inertia when it is rotated around the Y axis than when it is rotated around the X or Z axis because R is smaller when it is measured from the center of the cylinder to the Y axis.

Polar Moment of Inertia: an object's ability to resist torsion which is twisting. This is often represented by the symbol J.

Look at the piece of wood. When you rest it on a table and try to break it over the edge, it is much easier to break when the longest side of the cross section is pressed flat against the table. Try breaking it with the shortest side now and note which way is easier. This is because of the moment of inertia.

Example Questions:
The cylinder in the figure above has a radius of 3 m, a length of 20 m, and a mass of 200kg.

1) What is the moment of inertia about the Y axis?

2) What is the moment of inertia about the X axis?

3) What is the moment of inertia about the Z axis?

Forces, stresses, and moments are all important to a structure's stability. You will now do a project that involves everything you learned today.