**Newton’s Laws of Motion**

First Law: An object at rest stays at rest and an object in motion stays in motion with constant velocity unless acted upon by an unbalanced, outside force. (Inertia)

-The sum of all forces acting on an object is called the net force. Zero net force means zero acceleration and constant velocity. Velocity may or may not be zero.

Second Law:

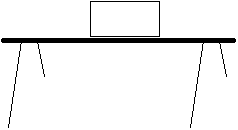
-This law allows us to calculate the net force acting on an object, the mass of the object, or the object’s acceleration when given values for the other two variables. This equation can be broken up into directions: for example, the net force acting in the x-direction is equal to the mass of the object multiplied by its acceleration in the x-direction, denoted . Forces are measured in Newtons, mass is measured in kilograms, and acceleration is measured in meters per second squared.

Third Law: For every action, there is an equal and opposite reaction.

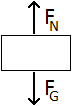
-Think about swimming. A swimmer pushes against the water. This moves the water. What moves the swimmer? The water pushes back!

**Free Body Diagrams**

The first step to completing a simple Newton’s Law problem is to construct the free body diagram. First, draw the object. It can be modeled as a simple square or circle; it doesn’t have to be pretty. Then, draw and label all forces acting on the object. (Remember Newton’s Third Law! If the object is exerting a force on something, that something is exerting a force on the object.)



Here is a box sitting on a table. To construct its free body diagram, we draw the box and all of the forces acting on it.



When an object is resting on a flat surface, the surface holds up the object by exerting a normal force on the object. The normal force is perpendicular to the plane of the surface. In this case, the only forces acting on the box are the force of gravity (also known as the box’s weight) and the normal force exerted on the box by the table. We know that the normal force is equal to the box’s weight because the box is at rest, and Newton’s Second Law tells us that if the acceleration is equal to zero, then the net force must equal zero.

**Example #1**

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The class is playing tug-of-war. The orange team is pulling with a force of 10 N to the left and the green team is pulling with a force of 12 N to the right. The rope has a mass of 5 kg. Ignoring the effects of gravity, calculate the acceleration of the rope.

Our first step is to construct the free body diagram.



The arrows represent the directions of the forces, and because we know their magnitudes, we can put them right on the diagram. Our next step is to calculate the net force. We do this using vector addition. Because the two forces act in opposite directions, we know that the net force will have a magnitude of the difference of the two forces and it will be in the direction of the larger force. Therefore, our net force is 2 N to the right.

We can now employ Newton’s Second Law to calculate the magnitude of the acceleration of the rope.

Finally, we must state our acceleration as a vector with both a magnitude and direction.

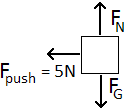
**The rope will accelerate at a rate of 0.4 m/s2 to the right.**

**Example #2**



A bowl of fruit is sitting on your kitchen table. When you push it to the left with a force of 5 N, it accelerates at a rate of 0.5 m/s2. Neglecting friction, what is the mass of the bowl of fruit?

Free body diagram:



Calculating net force:

We know that the downward force due to gravity is the weight of the bowl and that the table holds the bowl up by exerting a normal force on the bowl. Because the acceleration in the y-direction is equal to zero, FN=-FG. The only force remaining on the bowl is the pushing force. The net force on the bowl of fruit is 5 N to the left.

Applying Newton’s Second Law to calculate the mass:

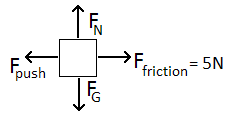
**The mass of the bowl of fruit is 10 kg.**

**Example #3**

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You are pushing a heavy box across a carpeted floor. The box has a mass of 30 kg and it is accelerating at a rate of 0.5 m/s2. Friction is opposing the motion of the box with a force of 5 N. How much force are you exerting on the box?

Free body diagram:



Calculating net force:

Once again, the normal force and the weight of the box will cancel each other out. The two forces that we need to calculate the net force are the force you are exerting on the box by pushing and the force of friction that is working against you. These forces act in the opposite direction, and since the box is moving, Fpush > Ffriction. We can now state that Fnet = Fpush­ – Ffriction, and that the net force will be to the left. Because we already have a magnitude for the force due to friction, Fnet = Fpush – 5N.

Applying Newton’s Second Law:

**You are pushing the box to the left with a force of 20N.**