# Dragged Racers: Worksheet

Fix the axles (so they don't move) for this friction experiment. Attach a twist tie between an axle of the car and the force sensor, so that pulling the force sensor will drag the car. Use the PASCO Explorer GLX to plot "Force vs. Time" and "Position vs. Time" under the "Graphs" display. ** **ZERO the force sensor by pressing the "ZERO" button!!**

Newton's Second Law: F=m*a

Force sensor

F

W
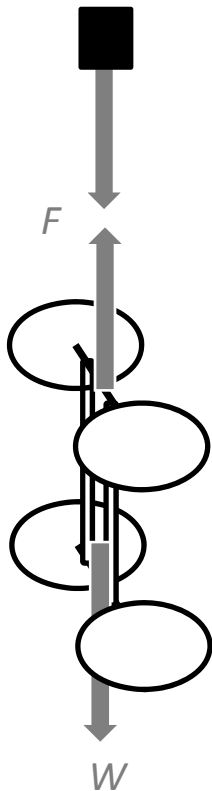
Hang the model in the air from the force sensor. While the model is hanging in the air, *gravity* acts upon it. This causes a downward force that we call **weight**.

As long as the model is only attached to the force sensor and is not moving, the sensed force, *F*, and the weight, *W*, are equal.

Press the "Play" button to take data for ≈1 sec. Use the "Smart Tool" (F3→ √), then the arrow buttons!

What is the Weight?

F = *W* = _____ Newtons

$$\left(1N=1\frac{kg\cdot m}{s^2}\right)$$

Sometimes accelerations other than Earth's gravity act upon an object. To find the relation between force and acceleration, we need to know the **mass** of an object.
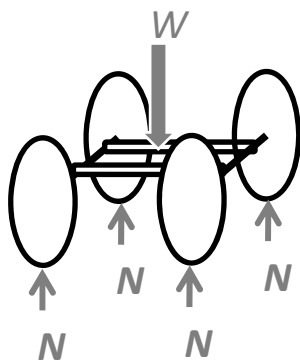
Calculate the mass of the model: *m*=_____ kg

$$F = m \cdot a$$

$$m = \frac{F}{a} = \frac{W}{g} = \frac{F}{9.8\ \frac{m}{s^2}}^{\frac{kg\cdot m}{s^2}} = \frac{F}{9.8}\text{kg}$$

←Look at how mass can be calculated using the equation F=m*a

When the model is resting on the floor, its *weight*, *W*, is balanced by the four wheels.

How do we confirm this:
**a) Visually?**

b) With an equation? (hint: is there acceleration?)

We'd like to calculate the friction acting on each wheel when the model is dragged along the floor. Because the weight is distributed between the **four** wheels, divide the *weight, W,* by **4**.

Remember Newton's 3rd law: for every action there is an equal and opposite reaction.

As long as the model remains motionless on the floor, the weight must be supported by the floor. We call the force of the floor *on the wheels* the ***normal force***, *N*, because it acts *at a right angle* to the floor:

What is the *Normal Force?* $N = \dfrac{W}{4} = $ _____ Newtons
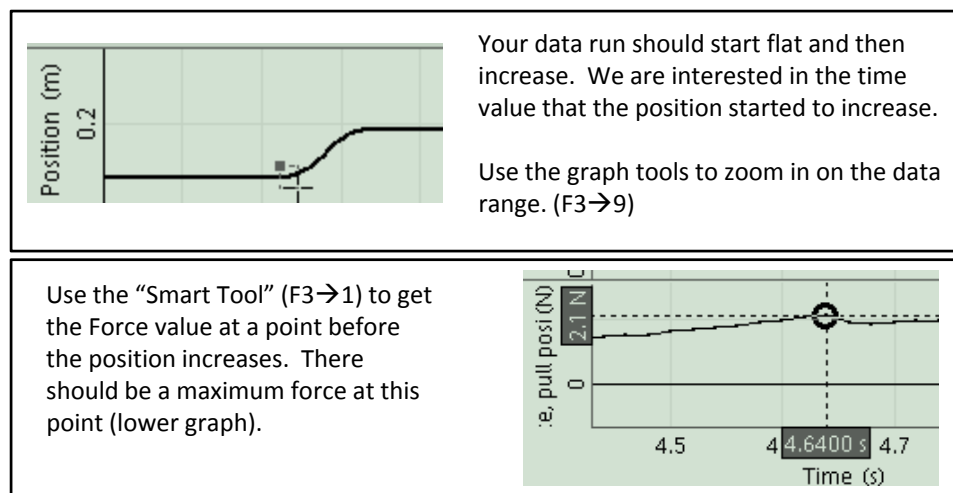
(a)

N

(b)

N
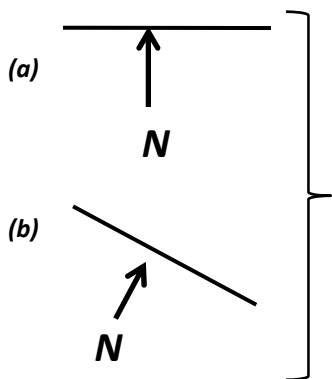
Which diagram represents the normal force acting on our model if it is sliding down a hill?____

Which diagram represents the normal force acting on our model while it is on the floor?____

When you have finished the calculations for mass and Normal force, collect friction data [on the PASCO Explorer GLX].

PROCEDURE:

1. Start the cars about 10 cm in front of the Motion sensor
2. Press the **START** button on the GLX to start recording data.
3. Pull the car gently ain front of the Motion sensor. Stop when you have collected a good data set or have pulled the car 15-20 cm.
4. Review the data on the GLX display by using "Zoom Select" and "Smart Tool" to magnify and view data values specific to static and kinetic friction:
   1. Zoom to the region of the "Position" curve where the values start to increase.
   2. Use the "Smart Tool" to identify the **maximum** force value in that region, which corresponds to the force needed to overcome Static Friction.

Your data run should start flat and then increase. We are interested in the time value that the position started to increase.

Use the graph tools to zoom in on the data range. (F3→9)

Use the "Smart Tool" (F3→1) to get the Force value at a point before the position increases. There should be a maximum force at this point (lower graph).

   3. Identify a part of the curve where the position is changing. If this is adjacent to the first region you looked at, use the "Move" tool to pan the graph to the left.

   Otherwise, "Auto-Scale" and use "Zoom" to select another region of the graph. Use the "Smart Tool" to estimate the average force values in this region; these force values correspond to the force imparted by Kinetic Friction.

   Note:
   Graphs may need to be toggled in order to use the "Smart Tool." Press **F3 → 9** to "Toggle Active Display."

What is the force from 4.2? $F_s=$_____ **Newtons**

What is the force from 4.3? $F_k=$_____ **Newtons**

Using the data we have collected, we can estimate the coefficients of friction between the axle-wheel models and the floor surfaces! Use the equations below to calculate the coefficient of static friction, μ_s, and the coefficient of kinetic friction, μ_k. Use the table to help guide your calculations.

$$F = \mu N \begin{cases} F_s = \mu_s N \\ F_k = \mu_k N \end{cases}$$

F	N	$\mu = \dfrac{F}{N}$
$F_s=$		$\mu_s=$
$F_k=$		$\mu_k=$

Save this worksheet in your folders. *We will revisit this!*

Reflection questions:
1. What is the relation between mass and weight?
2. Why was the "normal force" equal to the weight?
3. Why must objects overcome static friction before slipping?
4. What kind of friction -- static or kinetic -- will you want your mousetrap car to experience?