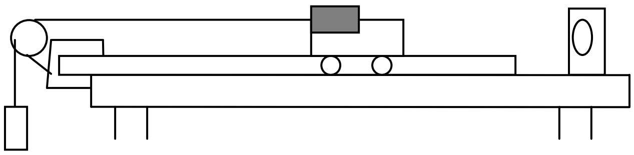
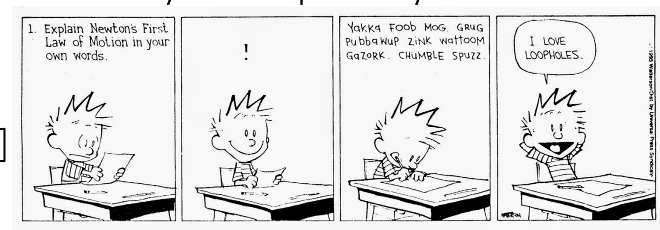
Name_____________________________________
Period________

Lesson 6: Combining Forces

6.1 <u>Experiment: Slowing Down While Moving Away and Speeding Up While Moving Toward The Origin</u>

(a) Set up the cart, meter stick, pulley, hanging mass, force probe, and motion detector as described/shown in class (below). You will examine the acceleration and applied force. Give your cart a push away from the pulley and make the measurements of motion and force.





(b) Use your force probe and motion detectors to create velocity and acceleration graphs of the motion. Sketch your velocity, acceleration, and force graphs of the motion. On your graphs label the regions corresponding to: (A) motion away from the origin, (B) stopped at the end of the motion, and (C) motion toward the origin.

PREDICTION:	– – – – –
ACTUAL:	———

velocity

time

acceleration

time

Force

time

(c) What (attached to the cart) pulls the cart after you let go?

Which direction does it pull?

The pulley, in this case, only changes the direction of the force, so it changes a downward force of gravity into a sideways force of tension.

(d) Use this formula to calculate the force of gravity exerted on the hanging mass and write it here:

F_{grav} = (mass in kg)x(9.8 m/s/s) = _______________

(e) How does the force applied by the hanging masses compare to the force measured on the force graph?

(f) During the cart's motion away from the origin, did the signs of the velocity, force, and acceleration agree with your predictions? If not, try to explain the signs.

(g) Did the velocity and acceleration during this part of the motion both have the same sign?

(h) Did the force and acceleration have the same sign?

What does that tell you about the direction of the force in relation to the direction of the acceleration? Explain.

(i) After you released the cart, was the force applied by the hanging mass constant, increasing, or decreasing?

Explain why this kind of force is necessary to cause the observed motion of the cart.

(j) Write down a simple rule in words which describes the relationship between the direction of the applied force and the direction of the acceleration for any motion of the cart.

(k) Is the direction of the velocity always the same as the direction of the force?

Is the direction of the acceleration always the same as the direction of the force?

In terms of its magnitude and direction, what is the effect of a force on the motion of an object?

(l) Describe the force and acceleration at the moment when the cart reverses direction.

(m) Based on your knowledge of acceleration and force, explain why the force and acceleration have the sign they have at this moment.

6.2 <u>Experiment: Cooperating Forces</u>

(a) Attach a small mass from a string attached to the front of the cart. Hang the mass over the pulley and release the mass to pull on the cart. Describe the resulting motion.

(b) What if you tie on another string with the same small amount of mass and release the cart with both strings. PREDICT: What do you think will happen to the motion of the cart?

(c) Now try it out and observe the motions in each case.
How did the acceleration when using one hanging weight differ from when two hanging weights were used?

(d) What can you conclude about forces that pull in the same direction?

6.3 <u>Experiment: Opposing Forces</u>

(a) Recall experiment 6.1, where the cart was pulled by a mass hanging from one string. Set up that experiment, only this time use the *force probe* on the other side of the cart to <u>hold it still</u> while hanging the mass off the pulley.

(b) What is the force from the hanging mass?

(c) What is the force from the force probe?

(d) What happens to the motion? Explain.

(e) What can you conclude about forces that pull in opposite directions?

6.4 Demonstration: Opposing Forces

(a) Fans mounted on carts can be used to exert forces in different directions. Two carts will be linked together, each having fans acting in opposite directions. Demonstrations will be performed showing the motion of the carts when one fan is on by itself, and when the other fan is on by itself. What do you observe about the motion of the cart system when each fan is on separately?

(b) Suppose that each fan pushed on the carts with the same magnitude (size) force. What do you predict would be the combined force acting on the carts when both fans are on?

(c) What do you predict would be the acceleration of the cart?

(d) Given your prediction for the acceleration, describe the motion of the carts:
(a) if they are initially at rest when the fans are turned on:

(b) if they are given a slight push after the fans are turned on.

(e) A demonstration will now be performed showing the motion of the carts when the two fans are on at the same time. Describe the motion of the carts. Were your predictions correct?

*Forces acting in opposite directions tend to cancel. The net (combined) force is equal to the difference in the strengths (magnitudes) of the pulls and acts in the direction of the larger of the two forces. The acceleration of any object is always the result of the net force acting on that object. The demonstration you just observed shows that the velocity of a cart does not change when the net force is zero.

6.5 Experiment: Once a Pull, Always a Pull?

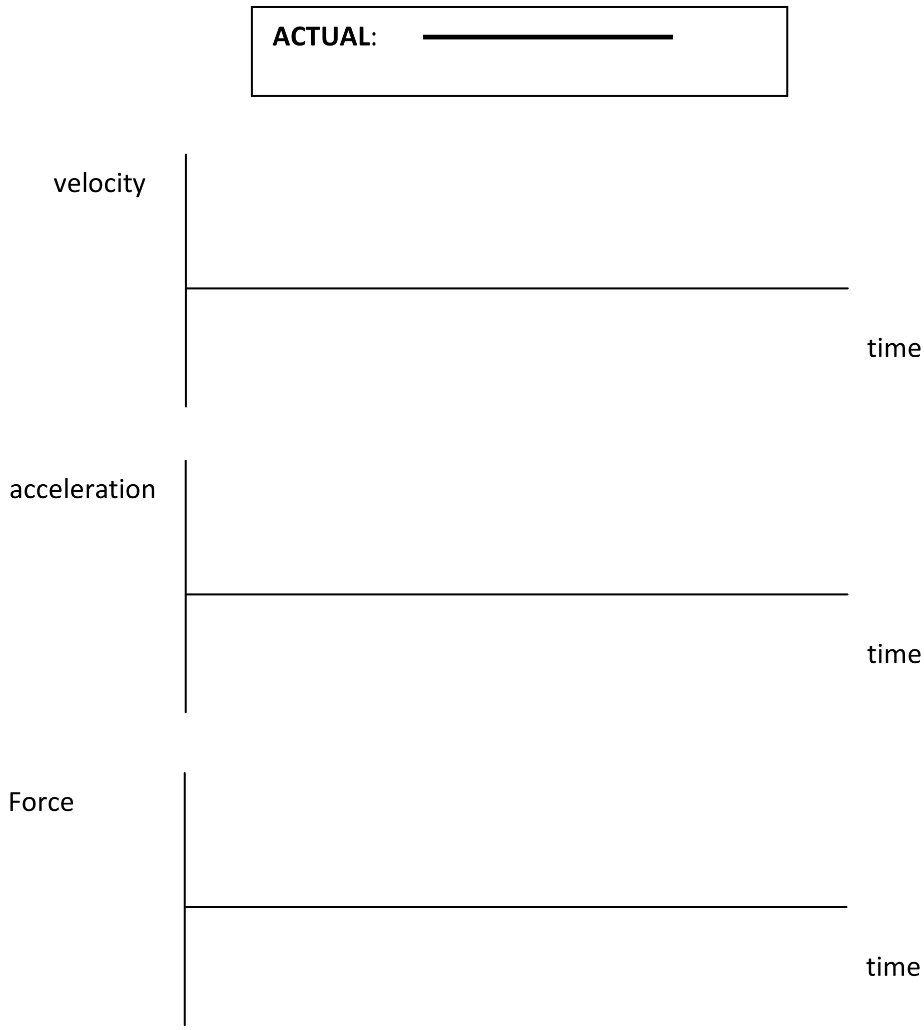
You have seen that to make the carts move with a constant velocity you need to apply a force to get them moving, but no applied force (or a very small force to balance the frictional force) was needed to keep them moving at a constant velocity.

(a) Suppose that you give the cart a little pull with a force probe to start it moving and then release it. Sketch your prediction of the velocity vs. time and acceleration vs. time graphs for the motion of the cart and the force vs. time graph of the applied force. Indicate on your sketches the moment when your pulling force acting on the cart is discontinued.

PREDICTION: _ _ _ _ _ _ _ _

(b) Test your predictions. The cart's friction should be as small as possible. Use the force probe to give the cart a short pull in the direction away from your zero position and then let go.

(c) Use the motion detector and force probe to obtain graphs of velocity, acceleration, and force vs. time. Sketch the graphs for the actual motion. Indicate with an arrow the time when the pull stopped.



(d) Do the velocity and acceleration graphs agree with your predictions? If not, how do they differ?

(e) What happened to the force of the pull after you released the cart? Explain.

(f) Do your results agree with what you observed in a previous experiment about the applied force needed to keep an object moving at a constant velocity? Explain.

6.6 Experiment: Acceleration and Mass

You can easily change the mass of the cart by placing masses on it, and you can apply the same force each time by using an appropriate hanging mass. By measuring the acceleration of different mass-cart systems you can find a mathematical relationship between the acceleration for the cart and its mass, with the applied force kept constant. That is what we intend to do here:

(a) **PREDICT**: What do you think will happen to the acceleration when you add more mass to the cart?

INSTRUCTIONS:

1. Using the setup from earlier, hang the 0.1kg mass off the pulley and pull back the cart to as far along the meter stick as you can manage.
   (Be careful that your mass won't come into contact with the ground during this experiment.)

2. Release the cart from rest at the other end and graph the motion (using the motion detector and force probe). Be sure to *catch the cart* before it runs into the pulley!

3. Repeat with different masses on the cart and fill in the data table. Remember to include the hanging mass in the total mass when you write it in the table.

Mass of Cart (kg):					
Situa-tion	Mass on Cart (kg)	Hanging Mass (kg)	Mass of System (kg) $m_{cart}+m_{on\ cart}+m_h$	Average Force Applied (N) [from graph]	Average Accel. (m/s/s) [from graph]
#1		0.100			
#2		0.100			
#3		0.100			
#4		0.100			
#5		0.100			

(b) Did the acceleration agree with your prediction?

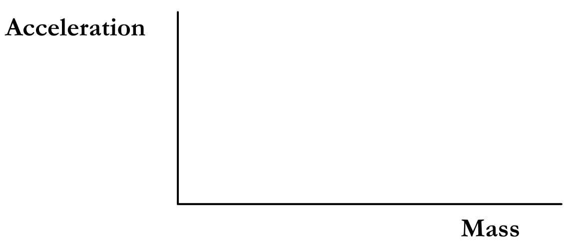
(c) Does the acceleration of the cart increase, decrease, or remain the same as the mass of the cart/mass system is increased? (What happens to the acceleration when you add more mass?)

(d) Create a graph of either Force vs acceleration or acceleration vs Force. Draw the shape and label the axes below:

6.7 <u>Exercise: Relationship Between Acceleration and Mass</u>

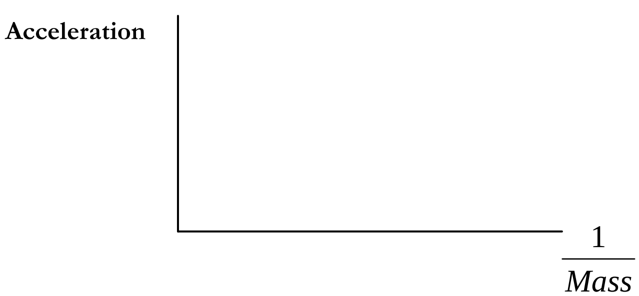
Use Excel or Logger Pro to find this:

(a) Construct a graph of <u>Acceleration vs Mass</u> using Excel or LoggerPro and sketch the results below:



(b) Is this a linear relationship (a straight line)?

(c) Try graphing <u>Acceleration vs (1/Mass)</u> and sketch that graph below:



(d) Does this come out linear? (Note: When a linear graph is obtained, it means that the x-axis quantity is directly proportional to the y-axis value.)

(e) When you have found the best fit, determine the slope and equation of the line and write them here.

(f) The slope can tell you what is constant in the experiment. What constant does the slope tell you?

(g) What appears to be the relationship between acceleration and mass of the cart/mass system when the force applied is held constant? (If you push just as hard on more mass, what happens to the acceleration?)

__________________ is directly proportional to _________________. We know this because the graph of

______________ versus _______________ produced a straight line.

6.8 Experiment: Acceleration and Force

This time we will keep the mass constant but change the force and measure the accelerations. You can easily change the force exerted on the cart by moving masses from the cart to the hanging mass. This keeps the total mass constant while changing the applied force. By measuring the acceleration of different mass-cart systems you can find a mathematical relationship between the force exerted on a cart and its acceleration, with the mass kept constant. That is what we intend to do here:

(a) **PREDICT**: What do you think will happen to the acceleration when you hang more mass off the pulley to pull harder on the cart (increasing the force) without changing the mass of the system?

INSTRUCTIONS:

1. Use your set-up from 6.1 for this experiment, but with more small masses added as "passengers". Starting with 0.1kg hanging mass, release the cart from rest at the far end of the meter stick and measure the time (using your stopwatch) and distance it traveled (using your meter stick).

2. Repeat by moving small masses from the cart to the hanging mass and fill in the data table.

Mass of Cart (kg):					
Situa-tion	Mass on Cart (kg)	Hanging Mass (kg)	Mass of System (kg) $m_{cart}+m_{on\ cart}+m_h$	Average Force Applied (N) [from graph]	Average Accel. (m/s/s) [from graph]
#1	1.900	0.200			
#2	1.800	0.300			
#3	1.600	0.500			
#4	1.500	0.600			
#5	1.400	0.700			

(b) Did the accelerations agree with your predictions?

(c) Does the acceleration of the cart increase, decrease, or remain the same as the net force applied to the cart/mass system is increased? (What happens to the acceleration when you push harder?)

6.9 Exercise: Relationship Between Acceleration and Force

(a) Construct a graph of Force vs Acceleration (Accel. on x-axis) and sketch your results below. (You can use Excel or LoggerPro to do this part)

(b) Is this a linear relationship (a straight line)?

If this doesn't produce a reasonably linear graph, try graphing Acceleration vs (1/Force) and Acceleration vs ($Force^2$). Which comes out linear? (Note: When a linear graph is obtained, it means that the x-axis quantity is directly proportional to the y-axis value.

(c) When you have found the best fit, determine the slope and equation of the line and write them here.

(d) What appears to be the relationship between acceleration and net force applied when the mass of the cart/mass system is held constant? (If you push harder on a mass, what happens to the acceleration?)

____________________ is directly proportional to __________________. We know this because the graph of

________________ versus _________________ produced a straight line.

6.10 Demonstrations:

Newton's First Law is also called the Law of Inertia, and there is a slightly different way to express it than to say that the acceleration of an object is zero (velocity is constant) when the net force acting on the object is zero. For instance, there are two ways in which the velocity can be constant: the object is not moving (e.g., its velocity is constant at zero) or it is moving (e.g., its velocity is constant and not zero). The Law of Inertia can be stated as follows: An object at rest will remain at rest if no net force acts on it. An object in motion will remain in motion with constant velocity if no net force acts on it. For the velocity vector to be constant both its magnitude and its direction must be constant.

For each of the demonstrations briefly explain how the Law of Inertia applies.

1. Air track moves beneath glider

2. Glider moves on frictionless air track

3. One light "rock" flies off faster than the other heavy rock

4. Cloth pulled out from under dishes

5. Bottom string breaks when it is pulled with a sudden jerk

6. Pan is launched out from beneath the eggs