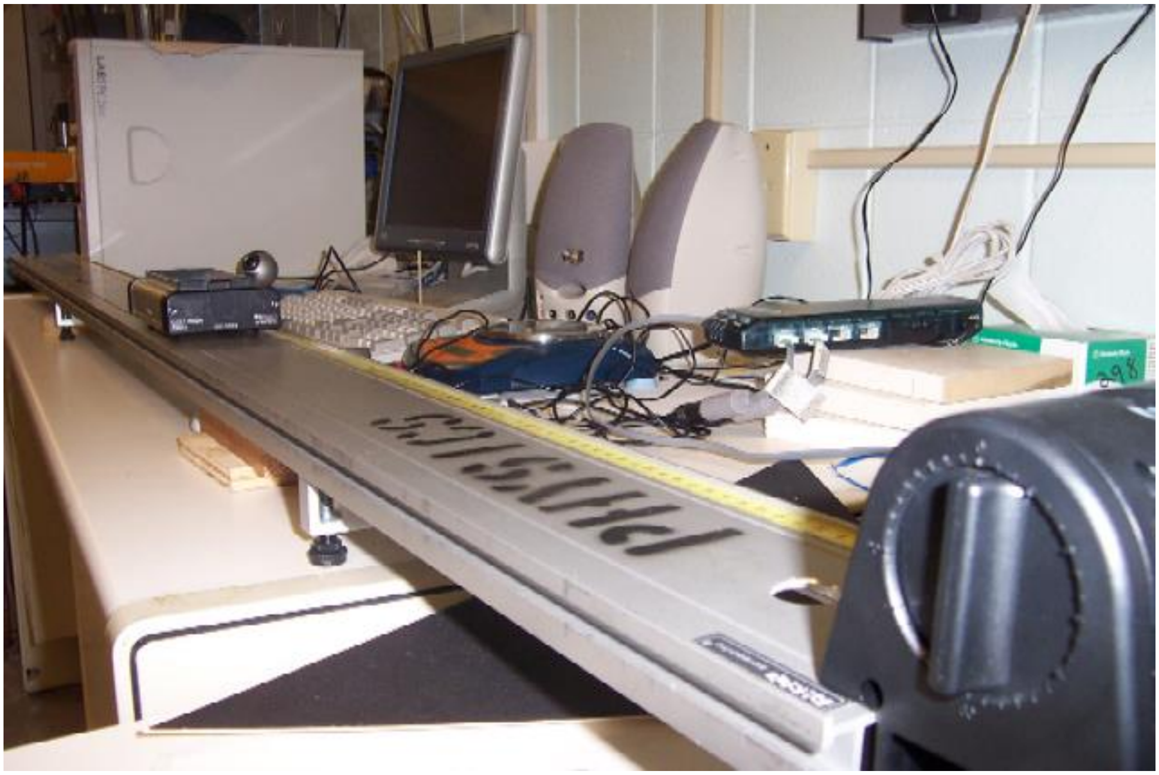
Newton's Laws I



Objective: To investigate, qualitatively and quantitatively, the motion of an object when acted upon by external forces.

Apparatus: Motion sensor, force sensor (2), Pasco track, Pasco cart, hanging masses w/built-in hooks (2), short loop string for one force sensor, meter stick, blue scissors jack or wood block for elevation

Introduction

You are already familiar with **Kinematics**, the study of motion that does not take forces and masses into consideration. In this lab you will find relationships between forces, masses and the resulting motion; this branch of mechanics is called **Dynamics**. For these series of experiments, do not take what you have learned from your lecture or textbook for granted - do the experiment and form your own conclusions

Procedure

Activity 1 (20pts)

Use the cart, track and a pen to determine a *qualitative* relationship between an object's motion and the net force acting on it (define one direction as (**+**), the other (**-**)). Examine the cart while it is at rest (not hitting or tapping cart), in motion, or in motion but being tapped constantly on one side with a pen. **Make sure that track is flat, meaning horizontal such that neither end is elevated.**

1. Fill in Part A in the table below (the table is only for Activity 1 only) with either 0, + or -, depending

on whether the quantity listed is zero, to the right, to the left. "Change in motion" is slowing down or speeding up. For instance, if the cart was moving to the right (+) but slowing down, the Change in Motion would be (-). If the net force was to the left, put a (-) in that box. (12 pts, 1 per box)

2. Fill in Part B in the table below, this time using a mass with built-in hook hanging from a Force Sensor (use Force Sensor.CMBL). Define up as (+). Note that you will be treating the mass (and not the Force Sensor) as the object. (6 pts, 1 per box)

Quantity	**A) Cart while it is**				**B) Mass while it is**	
	i. at rest (no hitting or tapping)	**ii. Moving, being hit with pen in dir. of motion**	**iii. Moving but pen is not hitting**	**iv. moving with pen tapping opposite direction of motion**	**i. at rest**	**ii. being pulled upwards from rest by hand (both mass & hand are moving)**
Motion						
Change in motion						
Net force						

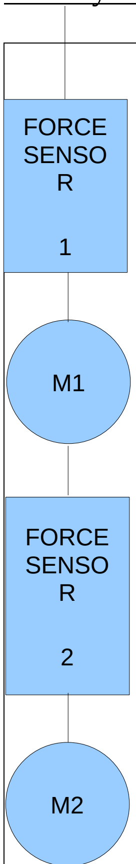
What is your conclusion, based on the above results, about how motion (or change in motion) depends upon net force? (2 pts)

Activity 2 (20 pts)

This activity has nothing to do with the table in Activity 1. Open up "FORCE SENSOR.cmbl". Using two force sensors, design an experiment to determine the magnitudes and directions of the forces between two objects that interact with each other directly (touching or pushing or pulling or colliding). Note that there is no need to use either of the brass double-hooked masses for the part. **Detail what your experiment will involve.** What is your conclusion? (20 pts)

(*Note: Makes sure your two sensors are set to the same range, e.g., both 10N or both 50N). If your force sensors do not register zero before they experience forces, you may have to press the Zero button near the top right of the Logger Pro window before you begin your experiment.)*

Activity 3 (30pts)



Preparation

Look at the setup on the left. You have, from top to bottom, Force Sensor 1, Mass 1, Force Sensor 2 and Mass 2, all connected to each other, and exerting forces on each other. Force Sensor 1 is hanging from a string, which you are holding so that the whole setup is above your lab desk.

Before connecting them all together, weigh both force sensors on the electronic scale at one end of the room. Use 200g for each mass in your calculations (no need to weigh masses).

Note that this is a **static** experiment. Draw a FBD (Free Body Diagram) for each of these four objects, clearly drawing a vector to represent every force on each object. **Note that** FBDs **should only include one object, isolated from the other objects**. Remember that the force of Gravity acts on all the objects. Include subscripts on the vector name that denote explicitly what is exerting a force on what; for instance, the force of gravity on M2$\vec{F}_{Grav\to M2}$. *Each FBD should only list the forces acting on each the four objects; nothing more.* (10 pts: 2 pts/object + 2 *free points*)

Based on your FBD, identify which forces the sensors would measure. Using your conclusion from Activity 2, and Newton's Second Law $\vec{F}_{netexternal} = m\vec{a}$, calculate and predict the reading on both force sensors when they are arranged as on the left. Show your calculation to your TA before proceeding. (10 pts)

Experiment

First open HANGING FORCE SENSORS.cmbl. Without putting any weight on the force sensors (or pulling/pushing on their hooks), position them individually in the orientation on the left and press the Zero button in Logger Pro. Then put together the setup as on the diagram on the left, press the Collect button, record your values and compare with your predictions. Note that this is a **static** experiment. If you did not come close, discuss the reasons for the discrepancy with your partner. (10 pts)

Activity 4 (15pts)

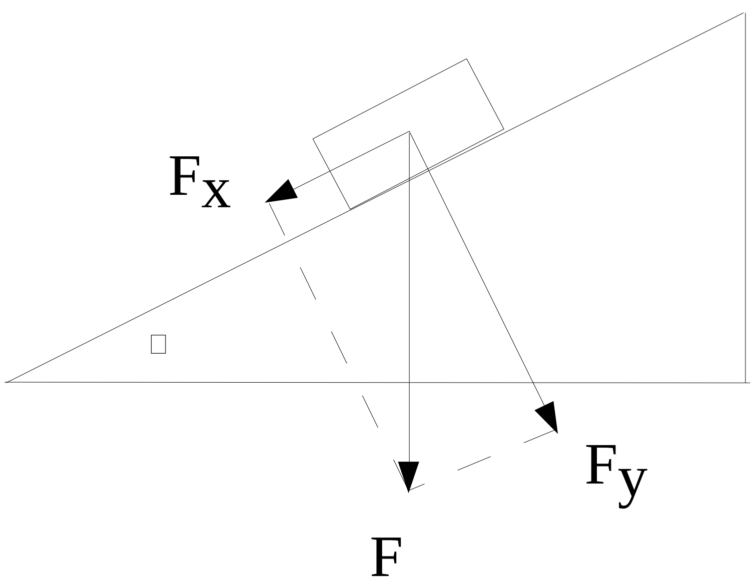
NOTE: THERE IS NO REASON TO REMOVE THE LEGS ON THE TRACK; JUST PUT THE BLOCK OR JACK UNDER ONE SET OF TRACK LEGS.

Elevate one side of your track (the same side as that with the motion sensor) so that it makes an angle of a few degrees above the plane of your lab table. Calculate, using your newly-acquired knowledge of dynamics, the (theoretical) time it will take for the Pasco cart to travel about 1.5 meters down the track at this angle of inclination. Open up Motion Sensor.cmbl and actually measure the time it takes, then compare to your experimental time to your theoretical prediction. You may find it useful to look at the table on the left of the graph to identify two time intervals corresponding to roughly 1.5m in distance; their difference will be the experimental time. (15 pts)

Remember that this is a **constant acceleration** problem, and that the usual kinematic equations like $x = x_0 + v_0 t + \frac{1}{2}at^2$ apply. Note the last term in this equation is a *quadratic* term.

HINT: When taking data with Logger Pro, it is helpful to note the points on the graph where the cart was released from your hand and when it was caught by your partner's hand. It is the region between these two time intervals which is of interest and, if you decide to do a curve-fit, you should not fit the parts of the graph that fall outside this interval.

The diagram below may be useful in helping to resolve forces into X and Y components; note that the force F being resolved here is the only the **gravitational** force; it should be straightforward to calculate the *acceleration* from the *force*:



F_x =**F** sinθ
F_y = **F** cosθ

Questions (15 pts)

Write the results from the four activities above in your lab report. Then answer these questions:

1. Does your result for Activity 1 conclusively prove Newton's First Law - why or why not? What modifications in equipment or conditions would you need to prove it conclusively? (4 pts)

2. Standing on an ice rink, two teenagers (wearing street shoes), one strong and one weak, are attempting to break a string in half by pulling on its opposite ends. If the only horizontal forces they exert are on the string, who is exerting more force, and why? (5 pts)

3. In order for a ***real*** car to accelerate forward from rest, an external force must act on it. Which direction does this external force act? *What* is providing this external force on the car? According to Newton's Third Law, there should be an opposite reaction force – *where* is this reaction force coming from, and *what* is it acting on? Note that a car's engine only exerts an internal force within the car, and not on the car's surroundings. (6 pts)