Experiment : Newton's 2nd Law

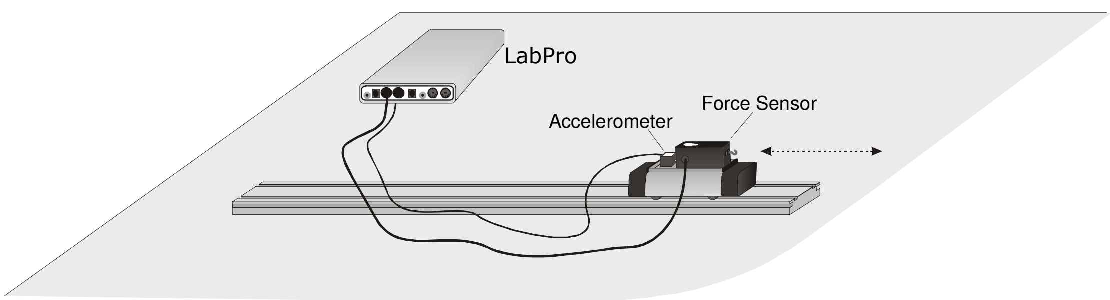
Objectives

a. Collect force and acceleration data for a cart as it is moved back and forth.
b. Compare force vs. time and acceleration vs. time graphs.
c. Analyze a graph of force vs. acceleration.
d. Determine the relationship between force, mass, and acceleration.

Introduction

How does a cart change its motion when you push and pull on it? You might think that the harder you push on a cart, the faster it goes. Is the cart's velocity related to the force you apply? Or does the force just *change* the velocity? Also, what does the mass of the cart have to do with how the motion changes? We know that it takes a much harder push to get a heavy cart moving than a lighter one.

A Force Sensor and an Accelerometer will let you measure the force on a cart simultaneously with the cart's acceleration. The total mass of the cart is easy to vary by adding masses. Using these tools, you can determine how the net force on the cart, its mass, and its acceleration are related. This relationship is Newton's second law of motion.



Materials

- LabPRO Interface
- Logger*Pro* software
- Force Sensor
- Accelerometer
- Collision track
- low-friction dynamics cart
- 0.500 kg mass

Preliminary questions

1. When you push on an object, how does the magnitude of the force affect its motion? If you push harder, is the change in motion smaller or larger? Do you think this is a direct or inverse relationship?

2. Assume that you have a bowling ball and a baseball, each suspended from a different rope. If you hit each of these balls with a full swing of a baseball bat, which ball will change its motion by the greater amount?

3. In the absence of friction and other forces, if you exert a force, *F*, on a mass, *m*, the mass will accelerate. If you exert the same force on a mass of 2*m*, would you expect the resulting acceleration to be twice as large or half as large? Is this a direct or inverse relationship?

Procedure

1. Connect the Low-g Accelerometer to CH1 on the LabPro interface.
2. Connect the Force Sensor to CH2 then set the range switch to ± 10 N.
3. Open the LoggerPro experiment file "09 Newtons Second Law".
4. Calibrate both sensors:

   Force Sensor

   a. Choose "Experiment"→ "Calibrate" then select the Force Sensor. In the calibration window, select the "Calibrate" tab then click on "Calibrate Now" button.
   b. Remove all weight from the Force Sensor and hold it vertically with the hook pointed down.
   c. Type **0** in the Reading 1 enter box.
   d. When the displayed voltage reading for Reading 1 stabilizes, click Keep.
   e. Add the 0.500 kg (4.9 N) mass to the hook of the Force Sensor.
   f. Type **4.9** in the Reading 2 enter box.
   g. When the displayed voltage reading for Reading 2 stabilizes, click Keep.
   h. Click on "Done".

   Accelerometer

   a. Choose "Experiment"→ "Calibrate" then select the Accelerometer.
   b. In the calibration window, select the "Calibrate" tab then click on "Calibrate Now" button.
   c. Point the arrow on the Accelerometer straight down. *Note: It is important that the sensor is vertical and held steady. You may want to hold the sensor against a table top to steady it.*
   d. Type **-9.8** in the Reading 1 enter box.
   e. When the displayed voltage reading for Reading 1 stabilizes, click Keep.
   f. Point the arrow on the Accelerometer straight up.
   g. Type **9.8** in the Reading 2 enter box.
   h. When the displayed voltage reading for Reading 2 stabilizes, click Keep.
   i. Click on "Done".

5. Attach the Force Sensor to a dynamics cart so you can apply a horizontal force to the hook, directed along the sensitive axis of the Force Sensor.
6. Attach the Accelerometer so the arrow is horizontal and parallel to the direction that the cart will roll. Orient the arrow so that if you *pull* on the Force Sensor the cart will move in the direction of the arrow.

7. Using a digital scale measure the mass of the cart with the Force Sensor and Accelerometer attached. Record the mass in the data table.
8. Place the cart on a level surface. Make sure the cart is not moving then zero both sensors.
9. Grasping the Force Sensor hook, begin data collection then move the cart back and forth on the table for several seconds, varying the motion so that both small and large forces are applied. *Make sure that your hand is only touching the hook on the Force Sensor and not the Force Sensor or cart body.*
10. Select "Examine" from the Analyze menu then move the mouse across the force *vs.* time graph. *When the force is maximum, is the acceleration maximum or minimum?*
11. Fit the force vs acceleration graph to a straight line using the "Linear Fit" function. Record the slope and y-intercept values for the fit, including the error, in the data table.
12. Select "Interpolate" from the Analyze menu then estimate the acceleration of the cart when a force of 1.0 N has acted upon it. Record the force and acceleration in the data table.
13. Repeat Step 12 for a force of –1.0 N.
14. Cut and paste each graph into Microsoft Word. Fit the graphs to a single page then print.

Trial 1		
Mass of cart with sensors (kg)		
Slope ± Uncertainty		**% Error:**
Y-Int ± Uncertainty		
	Force pulling cart (N)	**Acceleration (m/s^2)**
Force closest to 1.0 N		
Force closest to –1.0 N		

15. Attach the 0.500 kg mass to the cart then repeat Steps 7 – 14.

Trial 2		
Mass of cart w/ sensors + add'l mass (kg)		
Slope ± Uncertainty		**% Error:**
Y-Int ± Uncertainty		
	Force pulling cart (N)	**Acceleration (m/s^2)**
Force closest to 1.0 N		
Force closest to –1.0 N		

ANALYSIS

1. For each trial, how do the corresponding graphs of force *vs.* time and acceleration *vs.* time compare to each other?

2. Are the net force on an object and the acceleration of the object directly proportional? Explain.

3. What are the units of the slope of the force *vs.* acceleration graph? Simplify the units of the slope to fundamental units (m, kg, s).

4. According to Newton's 2^{nd} Law, the slope of the force acceleration graph should correspond to the mass. Do your measurements support this? *Be sure to take into account the uncertainty of the slope calculation.*

5. Calculate the % error between the slope and the measured mass values for Trial 1 and 2. Record the values in the data tables.