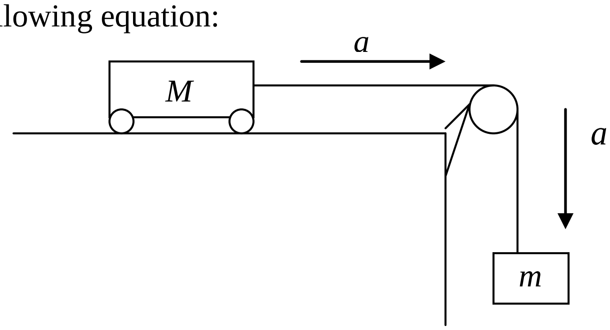
Move Your Mass Lab:
Newton's 2nd Law of Motion

OBJECTIVE: To predict the acceleration of a system.

INTRODUCTION

Consider the sketch below of the set-up you will be using. The motion of the cart in the horizontal direction is described by the following equation:



Equation 1: $Ma = F_T - F_F$

Where:
- M = the cart mass
- a = the cart's acceleration
- F_T = the tension in the string
- F_F = friction force

The tension in the string and thus the acceleration of the system is produced by the force of gravity acting upon the ***hanging mass (*** m ***)***. From its free-body diagram we get the equation that describes its motion:

Equation 2: $ma = mg - F_T$

We can solve for acceleration by substituting and combining these two equations:

Equation 3: $a = \dfrac{(mg - F_F)}{(m + M)}$

PROCEDURE

PART 1. FRICTION FORCE DETERMINATION

To do this portion of the lab, place the cart on the track and attach a small amount of mass (no more than 5 grams will be needed) to the hanger. Tap the cart gently. If the cart comes to a stop after tapping it, the force of friction must be greater than the weight pulling the cart. If the cart continues to accelerate after tapping it, then the weight must be greater than the friction force. When you have a weight attached that causes the cart to move at a constant velocity, then the weight is equal to the force of friction ($F_f = mg$). **Use a laptop and motion detector to verify that you have constant velocity**. Discuss how you used the laptop to determine this. Once you have done this, determine the force of friction. Report this force and all of your calculations within your write-up.

PART II. ACCELERATION PREDICTION

Select a new hanger mass m so that this mass gives you a weight that will exceed the friction force, but DOES NOT exceed 20 grams. Use the mass of the cart (M), the mass of the hanger (m), and the friction force (F_F) and ***calculate*** the theoretical value (A_T) for the acceleration of the system. Show all calculations on your write-up.

PART III. DATA COLLECTION

Set up your experiment using the values you selected for the prediction (Part II). Use the motion detector to measure the length of time it takes for the cart to travel a distance you have chosen. You will then measure the experimental acceleration in two ways.

A. Use a velocity-time graph to determine a region that shows constant acceleration. Then, on the acceleration-time graph use Logger Pro's STATISTICS function to find the average acceleration during this time and record it (A_A).

B. Use the equation $x = x_o + v_o t + \frac{1}{2}at^2$ to solve for *a* by measuring the necessary variables to solve for a from the computer generated graphs. Do not include in the distance the region where the cart starts from rest. This means that your initial velocity will NOT be zero. From the graphs, you therefore must determine t_1, t_2, v_o, x_o, and x. Record all values and use these to calculate a value for *a*. Record this value as (A_B).

PART IV. ANALYSIS

1. Compare your theoretical acceleration (A_T) to both experimental results (A_A & A_B) by calculating the % error. Show your work. Which of the two experimental results was closest to the theoretical value? Explain your results, including any discrepancies.

2. In Part 3B above, you were instructed to exclude the region where the cart started from rest. Why would you want to avoid this region in your acceleration determination?

3. Show that Equations 1,2, and 3 from the introduction are all variations of Newton's 2nd Law. In other words in your write-up, derive each of the equations on the front of this lab by starting from $\sum \mathbf{F} = m\mathbf{a}$. Basically you will be doing what you have already done in some warm-up problems and homework problems.