Physics 223
General Physics Lab
<u>Experiment 7: Newton's Second Law Theory and Procedure</u>

THEORY

Purpose

In varying the force on, and the mass of a system, we will examine the dynamics of that system through the lens of Newton's Second Law.

Dynamics

While "Kinematics" is the study of a system's motion, "Dynamics" is the study of why that motion occurs. According to Newton's Second Law (the most powerful dynamical tool that you will learn in this course), the acceleration of a mass is directly proportional (in both magnitude *and* direction) to the net force acting on that mass. Mathematically, we can write this:

$$\sum \vec{F} = m\vec{a}$$

where $\sum \vec{F}$ is the net force on a mass, m is the mass that the forces are acting upon, and a is the acceleration of that mass.

In this experiment, we will examine the dynamics of a low-friction cart as part of an Atwood's Machine. The (constant) gravitational force on a hanging mass will be redirected via tension force by pulley to pull the cart along a tabletop. The tension force pulling the cart will be measured by a force-probe attached to the cart, and the acceleration of the cart will be measured by a motion detector directed along the path of the cart's movement.

PROCEDURE

Part 1: A Quantitative Estimate of the Cart's Friction

All sliding or rolling objects have a certain amount of friction associated with their motion which cannot be eliminated.

We can quantify an estimate of the frictional forces in the cart using *phenomenological* approach. This means that although we cannot measure the frictional forces directly, we can use our knowledge of a known theory (Newton's Second Law) to make reliable predictions about them.

1) Place a small amount of mass (between 2 g and 5 g) on the end of the string that is attached to the force probe and runs over the pully.

2) Give the cart a gentle tap. Hold the force probe's wire so that it does not drag along the tabletop or in any way hinder the cart's motion.

   If the cart slows down after the tap, then the gravitational force on the hanging mass is less than then the frictional forces in the cart.

   If the cart speeds up after the tap, then the gravitational force on the hanging mass is greater than the frictional forces in the cart.

3) Adjust the amount of hanging mass until the cart moves along the tabletop at a constant speed*.

   If the cart moves at a constant speed, then the gravitational force on the hanging mass is equivalent to the frictional forces in the cart. Record the frictional forces in the appropriate cells of Data Table 1.

   Draw a free body diagram on the datasheet (Step 3) which includes these two forces on the cart. Assuming that the cart is moving at a constant speed, plug these forces into Newton's Second Law to convince yourself that they are equivalent.

   (*Every tabletop and cart are different, and will have different frictional forces!)

Part 2: Force Probe Calibration

The force probe mounted to the top of the low-friction cart is a sensitive instrument which needs to be re-calibrated each time it is turned on, after a long period of rest (longer than the time of the lab period), or after it experiences a large force or impulse, such as dropping it on the tabletop or letting it run into the bumper at the end of the travel-path.

(While the formal definition of impulse will not be discussed here, a large impulse should be considered any sudden "jarring" motion to the force probe.)

The calibration procedure will be demonstrated by your TA, and is enumerated here:

1) Open the "Newton's Second Law" *Logger Pro* program. This is the computer program that will interface with both the force probe and motion detector. The file-path on the lab desktop is:

Desktop/Student Files/Experiments/Newtons2ndLaw

You should see four blank plot areas: Force vs. Time, Position vs. Time, Velocity vs. Time, Acceleration vs. Time.

2) Orient the force sensor in the same way that it will be used to collect data (Resting horizontally on top of the low-friction cart).

3) Progress through the following *Logger Pro* menus:

"Experiment" → "Calibrate" → Choose "Dual Range Force"

And press: "Calibrate Now"

4) Enter "0" while the force sensor is under NO load. Then press "Keep".

5) Hang 50 g from the force sensor. *Be sure that the mass is not swinging!*
Enter ".49 N". Then press "Keep".

6) Press "OK"

Part 3: Force and Acceleration Data Collection

7) Record the (1x) mass of the cart in Data Tables 1 and 2

8) Hang 50 g (the mass hanger only) from the end of the cord. Position the cart approximately 40 cm in front of the motion detector. Push the "Start" button in the Logger Pro interface. When you hear the motion detector begin to click, let the cart go. **CATCH THE CART BEFORE IT HITS THE FOAM BUMPER!**

9) Highlight the appropriate *Force vs. Time* data. (Don't highlight the fringes of the run!) Press the STATS button to get the average (mean) measured force on the cart through its motion. Record this in the appropriate "Measured Tension" cell of Data Table 1.

10) Highlight the appropriate *Velocity vs. Time* data. Press the LINEAR FIT button to get the slope of the velocity plot. What does the slope of a velocity plot tell us? Record this measurement in the appropriate cell of Data Table 2.

11) Repeat Steps 7 – 10 with 100 g hanging from the end of the cord.

12) Double the mass of the cart. **Repeat "Part 1" to determine the new frictional forces in the cart.** Record this data in Data Table 1.

13) Repeat Steps 7 – 11 for the cart with double the original mass. Record this 2x mass in Data Tables 1 and 2.

Part 4: Theoretical Calculations

14) Using the work from your prelab, fill in Data Table 3.

15) Determine the "Calculated Tensions" and "Calculated Accelerations" using the formulae in Data Table 3. Record these calculated values in Data Tables 1 and 2.

16) Determine the Percent Difference between your calculated and measured tension and acceleration values. Record these values in the appropriate cells of Data Tables 1 and 2.