EXPERIMENT 4A
NEWTON'S SECOND LAW WITH COMPUTERS

I. THEORY

The purpose of this experiment is to test Newton's Second Law of Motion, which states that the net force acting on a body is equal to the product of the mass and the acceleration of the body.

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

When two or more bodies are combined into a system, Newton's Second Law applies to each mass individually, and also to the system as a whole; that is, the net force acting on the system is equal to the product of the total mass of the system and the acceleration of the center of mass.

In this experiment, a cart is placed on a level track. A string is attached to the cart and passes over a pulley and a mass is hung from the other end of the string. A sensor (Wireless Dynamics System Sensor =WDSS) attached to the cart measures the acceleration of the cart and the force the string exerts on the cart.

In our experiment, we will neglect any friction in the axle of the pulley as well as the mass of the pulley. This allows us to claim that the tension is the same at both ends of the string. (The tension at both ends of the string is very nearly equal for our pulley. The difference introduces only a very small error, much smaller than the error in the Equilibrium Lab – Experiment #4.)

We will test Newton's Second Law by plotting a graph of the tension in the string vs the acceleration of the cart. If Newton's Second Law is true, the data should produce a straight line and the slope of the line should equal the mass of the cart.

II. LABORATORY PROCEDURE

WARNING: NEVER PLACE THE CART ON THE LAB BENCH WITH ITS WHEELS IN CONTACT WITH THE BENCH. THE LAB BENCHES ARE NOT LEVEL AND THE CART MAY ROLL OFF AND BREAK ON IMPACT WITH THE FLOOR. WHEN PLACING THE CART ON THE LAB BENCH, **ALWAYS** PLACE THE CART ON ITS SIDE.

1. Place the track on the laboratory table so that the pulley extends over the edge of the table.

2. Plug in and power on the Laptop Computer.

3. Level the track lengthwise and crosswise.

4. Open the folder named Physics which you should find on the desktop of the computer. Open the file "Newtons2nd.cmbl" contained in the folder.

5. Turn on the Wireless Sensor (WDSS).

6. The WDSS is a Bluetooth device and you must do the following before your computer can get data from it. On the Menu Bar go to:
    Experiment → Connect Interface →Wireless → Scan for Wireless Devices
    Select your WDSS by name by checking the appropriate box and clicking "OK".

7. Before collecting data, you must zero the accelerometer and force sensor within the WDSS. To do this, place the cart on the track with no string attached. Click the "Zero" button which is next to the green "Collect" button. Check both boxes to zero both the accelerometer and the force sensor. Click "OK".

8. Run a string from the hook on the WDSS over the pulley and attach a weight hanger. Move the cart toward the far end (away from the pulley) of the track, making sure that any knots in the string are below the pulley. Click the collect button and then release the cart. CATCH THE CART BEFORE IT HITS THE ENDSTOP.

9. You should see two graphs on the screen. One shows force as a function of time. The other shows acceleration as a function of time. The acceleration graph should be zero before you release the cart, should rise to a positive constant value while the cart approaches the end stop, and should drop to negative when you catch the cart. We are interested in the positive constant value while the cart is accelerating uniformly. Select a region near the middle of this uniform acceleration by dragging the pointer with the "left mouse" button depressed. The selected region should now be highlighted. Click the button labeled "STAT". A window should appear giving you statistics on the data in the highlighted region. We are interested in the **mean** or average value for the acceleration. Click on the edge of the force graph (you should have the arrow, not the crosshair when you click). Again, click the "STAT" button. (If you clicked the force graph when you had the crosshair instead of the arrow, you lost the highlighted region and will have to reselect the time interval for statistics.)

10. Record the hanging mass (just the 50.0 g weight hanger for this run), the average (mean value) acceleration of the cart, and the average tension in the string.

11. Repeat steps 8-10 for the following hanging masses (including the weight hanger): 60.0 g, 70.0 g, 90.0 g, 100.0 g, 120.0 g, 130.0 g and 150.0 g.

12. Turn off the WDSS sensor. Close all programs on the laptop and shut it down from the "Start" menu.

13. Measure the mass of the cart with the sensor and mass attached. You will need to use a "1000.0 g" mass extender with the balance.

III. CALCULATIONS AND ANALYSIS

1. Plot a graph of the measured tension in the string versus the measured acceleration of the cart. Does your data appear to fall along a straight line? Does this agree with Newton's Second Law of Motion?

2. Draw in a best-fit line on your graph. Determine the slope of your line to 3 significant figures. How does the slope of your line compare with the mass of the cart? Explain why the slope should theoretically be equal to the mass of the cart and compute a percent error.

3. Does your best-fit line pass through the origin? Why is this the case?

4. Since the magnitude of the acceleration of the hanging mass and the cart are the same, we can compute an experimental value for the acceleration due to gravity from the results of each run. Draw a free body diagram for the hanging mass. Label the gravitational force "mg". Apply Newton's Second Law. (Keep everything symbolic since you will reuse your algebraic result for each run!) Solve your Newton's Second Law equation for "g". Make a table with a row for each run and columns for: Hanging Mass (g), Acceleration (m/s²), Tension in the String (N), and Calculated Acceleration Due to Gravity (m/s²).

5. Average your eight values for the acceleration due to gravity and calculate a percent error.

Name: _____

Lab Partners: _____

                   _____

NEWTON'S SECOND LAW

Mass of Cart, WDSS and Attached Mass: _____

Hanging Mass (g)	Acceleration ( )	Tension ( )