PHYS 1401
General Physics I

EXPERIMENT 5
NEWTON'S SECOND LAW

I. INTRODUCTION

The objective of this experiment is to measure the acceleration of an accelerated mass under various experimental conditions and to check the consistency of the result with Newton's Second Law. The experiment will be done on an air track. A mass, m, will hang over a pulley at the end of the air track and will pull another mass, M, along the length of the airtrack. Applying Newton's second law to both masses and neglecting friction, it is easy to show that the acceleration of the system is

$$a = \frac{mg}{(m+M)} \tag{1}$$

II. APPARATUS

Air track with accessory box, smart pulley, mass hanger with assortment of masses, LabPro and a computer.
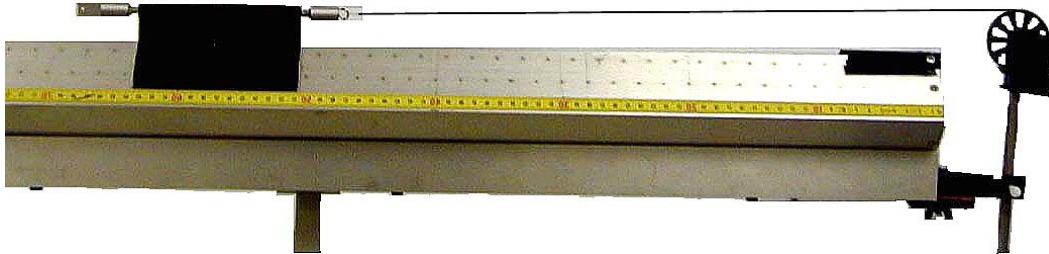

Figure 1: Air Track with Smart Pulley

III. EXPERIMENTAL PROCEDURE

1. Set up the apparatus as shown in figure (1). Connect the air hose to the air track and plug in the air compressor. Plug the smart pulley into input port Dig/Sonic1 of the LabPro.

2. Turn the computer on. The LabPro should be on.

3. Open the **Logger Pro** folder by double clicking on it. Open the folder titled Newton's 2nd Law. This will give you a screen showing a set of velocity vs. time axes. The computer is ready.

4. Balance the air track by following the procedure given by the instructor.

5. Using the masses given in the data table, attach a string (about 1.5 m long) to the hanging mass, m and to the glider on the air track, M. The glider must be balanced front and back and side to side. You should have a hook attached to the back of the glider similar to the hook attached to the front. Also the masses added to the glider must be divided half on the left and half on the right of the glider.

6. One of the students in the group will move the glider backwards until the hanging mass is just under the pulley. Another student member of the group will click on the Start button above the graph. Release the masses after a short pause. The hanging mass will fall downward pulling the glider along the air track. The computer has collected a set of data points of velocity vs. time and will plot a graph and draw the best straight line fit for the data of this run. The slope and v-axis intercept will be given below the graph. The slope of the line is the measured acceleration of the masses. Record it in the appropriate column in the data table.

7. Move 10 g (5 g from each side) from the glider and add it to the hanging mass and repeat step (6) obtaining the measured acceleration for this run.

8. Continue this process until all the excess mass has been transfered from the glider to the hanging mass. This will give you 6 data points. Notice that for all these points the total mass $(m + M)$ is constant.

9. Now for the second part of this experiment, you will obtain 6 data points where the accelerating force is kept constant. The accelerating force is the weight of the hanging mass.

10. Fix the hanging mass at 30 g. The mass on the air track is the glider. Repeat the above procedure obtaining the measured acceleration.

11. Repeat this process 5 times each time adding 20 g to the glider (10 g on either side) and measuring the acceleration.

12. You are finished with the experimental procedure. Before you disassemble your apparatus, show your data to the instructor or the lab assistant to make sure your data are ok.

IV. ANALYSIS

1. Draw the free-body diagram for the hanging mass, m and the glider, M. Apply Newtons 2nd law to each mass and derive the expression for the acceleration given above.

2. Complete the calculations required in the data table and show a sample calculation for each different calculation you make.

3. For the first 6 data points, plot the force in newtons on the vertical axis vs. the measured acceleration in m/s^2 on the horizontal axis. Draw the best straight line fit for the data and calculate the slope of this line. Show the calculation of slope on the same sheet as the graph. Give the SI units of the slope. Identify the slope with the quantity which was held constant for this part of the experiment. Calculate the % difference between the slope and the total mass.

$$\% \text{ difference} = \frac{|(m+M) - \text{slope}|}{\left(\dfrac{(m+M) + \text{slope}}{2}\right)} \times 100. \qquad (2)$$

4. For the second 6 data points, plot the measured acceleration on the vertical axis and the reciprocal of the total mass, $\left(\dfrac{1}{m+M}\right)$, on the horizontal axis. Draw the best straight line fit for the data, claculate the slope of the line and calculate the percent difference between the slope and the applied force.

5. Find the maximum percent difference between the experimental acceleration and the theoretical acceleration.

6. Write a conclusion summarizing your results. Comment on the success of this experiment. Are your results consistent with Newton's 2nd law? Explain any percent differences that are larger than 10%. What do you think are the two most important sources of error?

Trial No.	Hanging Mass m (kg)	Glider Masss M (kg)	Net Force $F_{net} = mg$ (N)	Experimental Acceleration (m/s^2)	Theoretical Acceleration (m/s^2)
				Experiment (5) Data Table: Constant Total Mass $= m + M =$	
1	0.010	Cart + 0.050			
2	0.020	Cart + 0.040			
3	0.030	Cart + 0.030			
4	0.040	Cart + 0.020			
5	0.050	Cart + 0.010			
6	0.060	Cart			

Experiment (5) Data Table: Constant Net Force, $F_{\text{net}} = mg =$					
Trial No.	Hanging Mass m (kg)	Glider Masss M (kg)	Total Mass $m + M$ (kg)	Experimental Acceleration (m/s^2)	Theoretical Acceleration (m/s^2)
1	0.030	Cart			
2	0.030	Cart + 0.020			
3	0.030	Cart + 0.040			
4	0.030	Cart + 0.060			
5	0.030	Cart + 0.080			
6	0.030	Cart + 0.100			