PHYS 103 LAB 5 FORCES, NEWTON'S LAWS

INTRODUCTION

In this laboratory you will investigate Newton's Laws. You will use **Force Sensors** to measure *forces*. You will use **Motion Sensor** to find acceleration. You will tabulate your results using **Microsoft Excel**.

THEORY

Newton's Laws are a set of basic rules that tell us how objects move under the action of *forces* or in their absence. Newton's 1st Law tells us that unless an external *force* compels an object to change its course it will remain stationary or it will continue to travel along a straight line with a fixed *speed*. Whatever the nature of a *force*, according to Newton's 1st Law it has the ability to change the object's *position* and *velocity*.

Newton's 2nd Law tells us that the *acceleration* of the object on which a net *force* is exerted is directly proportional to the imposed net *force* and inversely proportional to the object's *mass*, and that the *acceleration* is directed in the same direction as the imposed net *force*. In mathematical language we write:

$$\vec{\boldsymbol{a}} = \frac{\vec{\boldsymbol{F}}_{\mathbf{net}}}{m} \qquad (1)$$

where $\boldsymbol{a}$ is the *acceleration*, $\boldsymbol{F}_{\mathbf{net}}$ the net *force*, and m the *mass* of an object. More often we see this equation rewritten in the form

$$\vec{\boldsymbol{F}}_{\mathbf{net}} = m\vec{\boldsymbol{a}}. \qquad (2)$$

In **PART 1** of this lab you will use the dynamics carts moving on a nearly frictionless track to check the validity of Newton's 2nd Law. The experimental setup for this **PART** is shown in figure 1 below. The **Force Sensor** attached to the cart will measure the force with which the cart is pulled along the track (which is the net force acting on the cart since the other two forces acting on the cart: gravity and the normal force balance each other), while the motion sensor will allow us to measure the cart's acceleration.

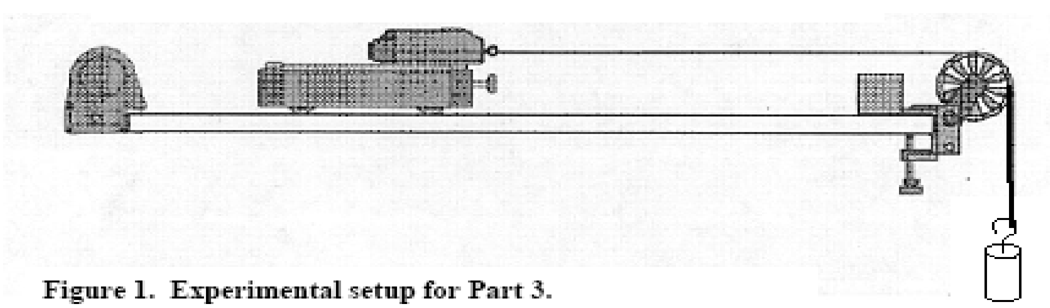

Figure 1. Experimental setup for Part 3.

Newton's 3rd Law tells us that if one object exerts a *force* on another object that other object will exert an equal and oppositely directed *force* on the first object. That means that if, for example you are pushing a chair with your hand, the chair pushes your hand back with equal and oppositely directed *force*. In **PART 2** of this lab you will use **Force Sensors** to verify Newton's 3rd law.

PROCEDURE

PART 1 NEWTON'S 2ND LAW

1. Physically connect the **Force Sensor** to the analog channel A of the **Interface Box**.

2. Open **Data Studio** and **'Create Experiment'**.

3. From the list of sensors in the **'Experiment Setup'** window select **'Force Sensor'** and then drag the **'Force Sensor'** icon over the analog channel A on the image of the **Interface Box**. Set the sample rate to 100 Hz.

4. Create a graph of *force* vs. *time*. Press the **'START'** button on the top of the **Data Studio** screen to see if the **Force Sensor** is tared to zero. If needed re-tare it. **'STOP'** the run and delete the data.

5. Hang a *mass* of 0.5 kg on your **Force Sensor** and hold it stationary. It is important that you hold the sensor really steady; try supporting it as best you can. Press the **'START'** button, collect data for a few seconds, and **'STOP'** the run. Select the data corresponding to a time interval when the reading of the **Force Sensor** is the most stable and find the mean value of the force for the selected data using **'Σ'** button on the tool bar of your graph window. Does the mean value match what is expected for 0.5 kg mass?_ Is your **Force Sensor** calibrated well?

NOTE: You will be using Force Sensors frequently in this lab. They often lose their calibration so each time check if they work properly by hanging a known mass (like 0.5 kg) on the sensor and checking that the reading is correct. Make this a part of your routine whenever you use Force Sensors.

6. Reattach the **Force Sensor** to the dynamics cart. Use the electronic scale to measure the *mass* of the dynamics cart with the attached **Force Sensor**. NOTE: hold the cord of the force sensor without pulling on it. We do not wish to include the cord's mass in this measurement. Record this value in **a Microsoft Excel** table similar to table 1 (column A).

7. In **Data Studio** connect **'Motion Sensor'** to the digital channel 1 on the image of the **Interface Box**. Set the sample rate to 100 Hz.

8. Physically connect the **Motion Sensor** to digital channels 1 and 2 of the **Interface Box** as shown in your **'Experiment setup'** window. Check to make sure that the **Motion Sensor** is set to the short-range designation.

9. Place the dynamics cart on the track making sure that its wheels are in the grooves of the track. Now level the track using its adjustable feet so that the cart placed at rest remains at rest.

10. In **Data Studio,** in addition to the *force* versus *time* graph, create a *velocity* versus *time* graph.

11. Tare the **Force Sensor** when it is positioned horizontally and when nothing pulls on its hook.

12. Place the cart about 15 cm in front of the **Motion Sensor** and hold it there. Attach the string's loop to the hook of the **Force Sensor.** Have your partner place the string over the pulley and attach a 200 g *mass* to the other end of the string as shown in figure 1. **CAUTION:** the hanging mass should hang no more than 20 cm above the floor. If needed lengthen the string. Place the bin with the rubber foam on the floor under the hanging mass. Be careful that the weights won't hurt anyone's toes on the way down and as they strike the floor.

13. Have your partner press the **'START'** button in **Data Studio** and immediately release the cart. **CATCH THE CART** before it gets to the other end of the track and hits the pulley. Have your partner press the **'STOP'** button

in **Data Studio** as soon as the hanging mass hits the floor. At all times keep the **Force Sensor's** cord out of the way of the cart.

14. Examine the graphs of *velocity* versus *time* and *force* versus *time* for the time when the cart moves, pulled by the *mass.* Select the smoothest part of the data corresponding to that time interval, preferably towards the beginning of the run.

15. In the *velocity* versus *time* graph do a linear fit of the selected data to find the acceleration. Record this value in **a Microsoft Excel** table similar to table 1 (column C). Also, record the value of the parameter ***r*** (column D).

16. In your table (column E) calculate the magnitude of the *force* using equation (2) and the measured value of acceleration.

Table 1.

M_{cart} (kg)	$m_{hanging}$ (kg)	a_{expt} (m/s^2)	r	$F_{calc} = M_{cart}\, a_{expt}$ (N)	F_{expt} (N)	% difference
	0.2					

17. In the *force* versus *time* graph find the mean value of the force for the selected data. Record the value of the force's magnitude in **your Microsoft Excel** table (column F).

18. Compare the calculated and the measured values for the force by calculating the % difference.

19. Discuss your results:

a) Was the *velocity* versus *time* data linear? Was your fit good?
b) Did you confirm Newton's Second Law (within the accuracy of the measurement)? Discuss.
c) Were your measured values for acceleration (column C) close to the accepted value of *g*? Should they be? Why or why not?
d) Draw a free body diagram for the cart while it was in motion. Make sure to include all forces exerted on the cart.
e) Draw a free body diagram for the hanging mass while it was in motion. Make sure to include all forces exerted on the hanging mass.

22. Print your **Excel** spreadsheet.

Part 2 Newton's 3rd law

1. Connect two **Force Sensors** to the analog channels A and B of the **Interface Box** (and disconnect them from the carts – **please take care not to lose the screw)** both physically and in **Data Studio.** Set the sample rate to 100 Hz for both.

2. Create a graph of *force* vs. *time* for the first **Force Sensor**. Drag the second **'Force Sensor'** icon from the **'Data'** window to the graph so that both sensor's readings will be displayed together in one graph**.**

3. Check that your **Force Sensors** are tared and are calibrated properly. Remember to re-tare the sensors before each measurement, holding them in the position in which you'll use them.

4. Attach two **Force Sensors** together by their hooks and place them horizontally on the table. Hold on to one of the **Force Sensors** while your partner holds on to the other one. Now pull on the **Force Sensor** and play "tug of war" with your partner. Vary the tension with which you pull and observe the graph **BUT DO NOT EXCEED 50 N OR YOU'LL DAMAGE THE SENSOR**. Also make sure that the metal hooks of the sensors remain in contact all the time. Does your partner have to pull on his/her **Force Sensor** in order to keep the **Force Sensors** stationary?

5. If you pull the **Force Sensor** more strongly does your partner have to pull on his/hers **Force Sensor** more strongly in order to keep the **Force Sensors** stationary?

6. Are the readings of the two **Force Sensors** the same?

7. Did you confirm Newton's 3rd law? Discuss.

8. Sketch a free body diagram for each of the **Force Sensors SEPARATELY!!!**

9. Print your graph.

Print all your tables, and attach them to your report.
Whenever possible SAVE PAPER.
Delete your files from the computer.
Disconnect all equipment, close all applications, and log off your PC.
DO NOT TURN THE COMPUTER OFF.
Make sure you leave the classroom as you found it.

LAB 5 REPORT

Group name:...

Partners' names:...

....

....

INTRODUCTION:

DATA PRESENTATION:

PART 1 NEWTON'S 2ND LAW

21. a)

b)

c)

d)

e)

PART 2 NEWTON'S 3RD LAW

4.

5.

6.

7.

8.

REMINDERS: Include units.
Make sure to attach all your data and graphs. No data = No credit
Please do not hand in the manual, just the report.

CONCLUSION: