Phys1111: Force, Mass, and Acceleration

Name:

Group Members:

Date:

TA’s Name:

Learning Objectives:

I. Understand how net force is related to mass, acceleration and velocity.
II. Use smart carts to measure force, velocity, and acceleration.
III. Learn about proportional and inversely proportional graphs.

Apparatus: computer, low-friction smart cart, two track supports, two cart stoppers, cart masses (four 250 g), track, pulley, string, 5 g mass hanger, and masses (one 10 g and one 20 g)

Part A: Identifying Forces and Making Predictions
We are going to investigate the connection between the force on a cart and its acceleration.

Set up the equipment: Set-up your smart cart and track apparatus as shown below. Set the track on the table so one end is hanging off. Level the track so that the cart will stay at rest and orient the +x direction of the cart toward the pulley so that cart’s velocity and acceleration will be positive in that direction. Attach the pulley so that it is on the end hanging off the table. Hook the length of string on the force sensor hook, run it through the hole of the cart stopper, then over the pulley, and attach to the 5 g mass hanger over the end. Adjust the pulley height so that the string is level. Think: Why does the string need to be horizontal?

1. The system of interest here is the cart. List the forces acting on the cart once it has been released. Also draw the free body diagram for the system.
2. Prediction: Draw lines on the velocity, acceleration and force graphs below predicting the shapes of the curves for the cart after being released.

![Graphs](image)

**Part B: Measuring Force and Acceleration**

**Setting up the Sensors and Capstone:** Launch Capstone on your computer then start a new experiment and select three displays. Select one display to be velocity, one to be acceleration, and the third to be force. Make sure to select the correct smart cart by matching the smart cart number. Set the number of decimal places to 3 for each variable by choosing *Data Summary* on the left side menu bar and selecting the *Properties* for each measurement then selecting *Numerical Format*. After changing *Number of Decimal Places* to 3, click OK and proceed to the *Properties* for the next variable. Detach or make the string go slack before the force sensor and see if the force sensor registers zero. If not see instructor if you need help with this.

You may need to change the sign of the force sensor if required. Force should be shown positive when you slightly pull the hook. If required, do this by choosing *Data Summary* on the left side menu bar and selecting the *Properties* for the *Force Sensor* then checking the *Change Sign* box.

**First Experiment:** Now you are ready to make your first run just with the mass hanger. Have another team member start taking data. Place the cart as shown in the figures above. Let go off the cart as soon as the clicking sound is heard. Catch the cart just before it crashes into the cart stopper.

The string should not touch the cart stop during the run. Make any changes if necessary.

3. How does your data compare with your prediction for the velocity graph?

4. How does your data compare with your prediction for the acceleration graph?

5. How does your data compare with your prediction for the force graph?
6. Are the sign of the acceleration and the sign of the force the same? _____________
   Is this consistent with what you know about the direction of the tension force on the cart and the
direction of the acceleration? Explain.

7. Explain how the velocity and acceleration graphs are related to each other.

8. Explain how the acceleration and force graphs are related to each other.

9. Now from these graphs we will measure the magnitudes of the average force and average acceleration
   of the cart during the time it is moving freely. To do this, select the appropriate data by putting a
   rectangle around the data points, and then selecting "mean" from the "Statistics" button at the top of
   the window, which is shown under the summation sign sigma, "Σ". When you select, choose data only
   for the appropriate portion of the experiment when the situation is the same as you identified in your
   free body diagram. That is, you should leave off the time when you are touching the cart and also the
time when the hanger is on the floor and the string is slack. If your acceleration vs. time data is noisy,
you can instead find the average acceleration using the slope of the velocity vs. time graph as you have
done before. Record this data below.

   \[ \text{Average Force} = \] ______________

   \[ \text{Average Acceleration} = \] ______________

   Remember there are units for each of these quantities.

   \[ \text{Have your TA check your graphs and initial below before you go on.} \]

   \[ \text{TA initials:} \]
Part C: Relationship Between Net Force and Acceleration

10. Your task is to figure out the value for the acceleration of the cart for different tensions of the string. Adding different masses onto the hanger will change the tension of the string. Change masses on the hanger and repeat. Record the average force (tension of the string) and the average acceleration for each added mass in the table below. You already found the data for Hanger Only in Question 9. Now complete the rest of Table 1.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Magnitude of Acceleration (m/s²)</th>
<th>Magnitude of Force (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hanger Only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hanger + 10 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hanger + 20 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hanger + 30 g</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

More Analysis: Copy the acceleration and force data from your table into Excel. Then create a graph of force vs. acceleration. If your graph is far from being a nearly straight line, pick out the most suspicious data point and re-do that run to check your data. You may do one extra mass point if time permits to get a much better graph.

11. Did your force vs. acceleration data give you a linear relationship?

12. What should the slope of the force vs. acceleration graph be equal to? Explain how you know.

13. Add a linear fit and determine the slope. Copy and paste the graph into your Word document.

What is the slope of your force vs. acceleration graph? Make sure you include units.

Slope = ____________________________

14. Now determine the mass of your system (the cart).

Mass = ____________________________

15. How does your slope compare to the mass of your system?

16. Summarize the relationship between force, mass, and acceleration found from your data.
Part D: Relationship between Mass and Acceleration

17. Now we want to repeat the experiment keeping the force constant and changing the mass of the cart to see how mass affects the acceleration. We will keep the force constant by putting 20 g on the hanger for each run. We will change the mass by adding black rectangular masses to the cart. Record force, mass and acceleration below.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Mass (kg)</th>
<th>Acceleration (m/s(^2))</th>
<th>Force (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cart and force sensor hook</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cart, sensor &amp; 250 g</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cart, sensor &amp; 500 g</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cart, sensor &amp; 750 g</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cart, sensor &amp; 1000 g</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Copy the acceleration and mass data from your table into Excel. Insert a new column and use a formula entry in Excel to calculate 1/mass for each row of your table. Then create a graph of acceleration vs. 1/mass. Is your graph a nearly straight line? If not, pick out the most suspicious data point and re-do that run to check your data. Add a linear fit and determine the slope. **Copy and paste the graph into your Word document.**

18. What is the slope for the fit of your acceleration vs. 1/mass data? Make sure you include units.

   Slope = ____________________________

19. The force should have been nearly the same in all of these runs. Determine the average force on your system from the table above. Remember units.

   Force = ____________________________

20. How does your slope compare to the average force on your system?

21. Summarize the relationship between force, mass, and acceleration you found from this part of the experiment.
Part E: Conclusions

22. What is your overall conclusion about this experiment and what it says about Newton’s Second Law?

23. Give evidence from your experiments to support the conclusions you made above.

Instructions on how to submit the graphs:
1. Open a word document and type the names of all present group members.
2. Paste force vs. acceleration graph with fit line from Part C.
3. Paste acceleration vs. 1/mass graph with fit line from Part D.
4. Please be smart about formatting of the Word document so you don’t waste paper.
5. Print your Word document and staple it to this lab write-up for one member of your group.