

# Force, Mass, and Acceleration

Name:

Group Members:

Date:

TA's Name:

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## Learning Objectives:

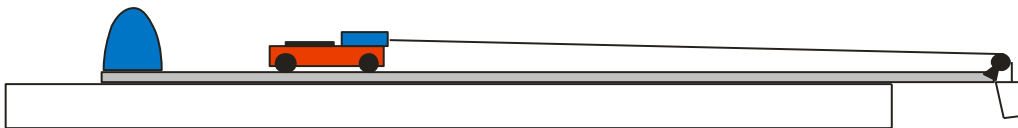
- I. Explore how force is related to acceleration and velocity.
- II. Learn about using force sensors.
- III. Develop a quantitative understanding of the force relationship.
- IV. Learn about proportional and inversely proportional graphs.

**Apparatus:** computer, motion sensor, force sensor, interface, low-friction cart, track, two track supports, cart masses (one 500 g and two 250 g), pulley, string, 50 g mass hanger, masses (one 10 g and two 20 g).

## Part A: Force and Acceleration

We are going to investigate the connection between the force on a cart and its acceleration.

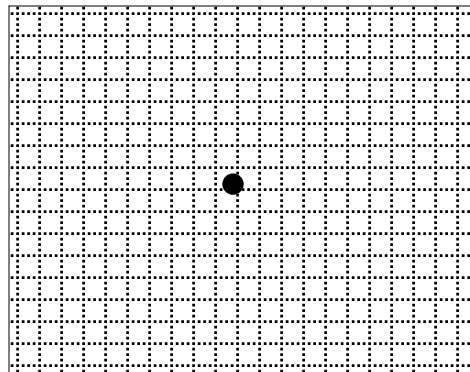
**Set up the equipment:** Set-up your cart, track, motion and force sensor as shown by your instructor. Set the track on the table so one end is hanging off, place the motion detector at the other end. Level the track so that the cart will stay at rest. Attach the pulley so that it is on the end hanging off the table. Attach the force sensor to the cart by using the screw. Make sure the screw goes through the hole labeled "cart" and not "IDS bracket." Hook the length of string on the hook of the force sensor, run it over the pulley, with the 5 g mass hanger over the end. Place 20 g of mass onto the hanger. Adjust the pulley height so that the string is level. See diagram below.



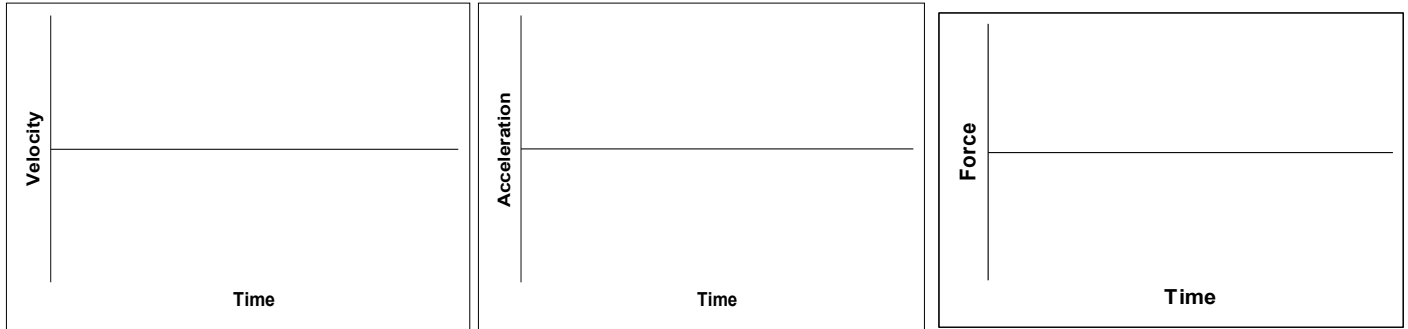
1. The system of interest here is the cart and the force sensor attached to it. Identify the forces acting on our system once you have released the cart. Then draw the free body diagram for the system.

Identify the forces on the system

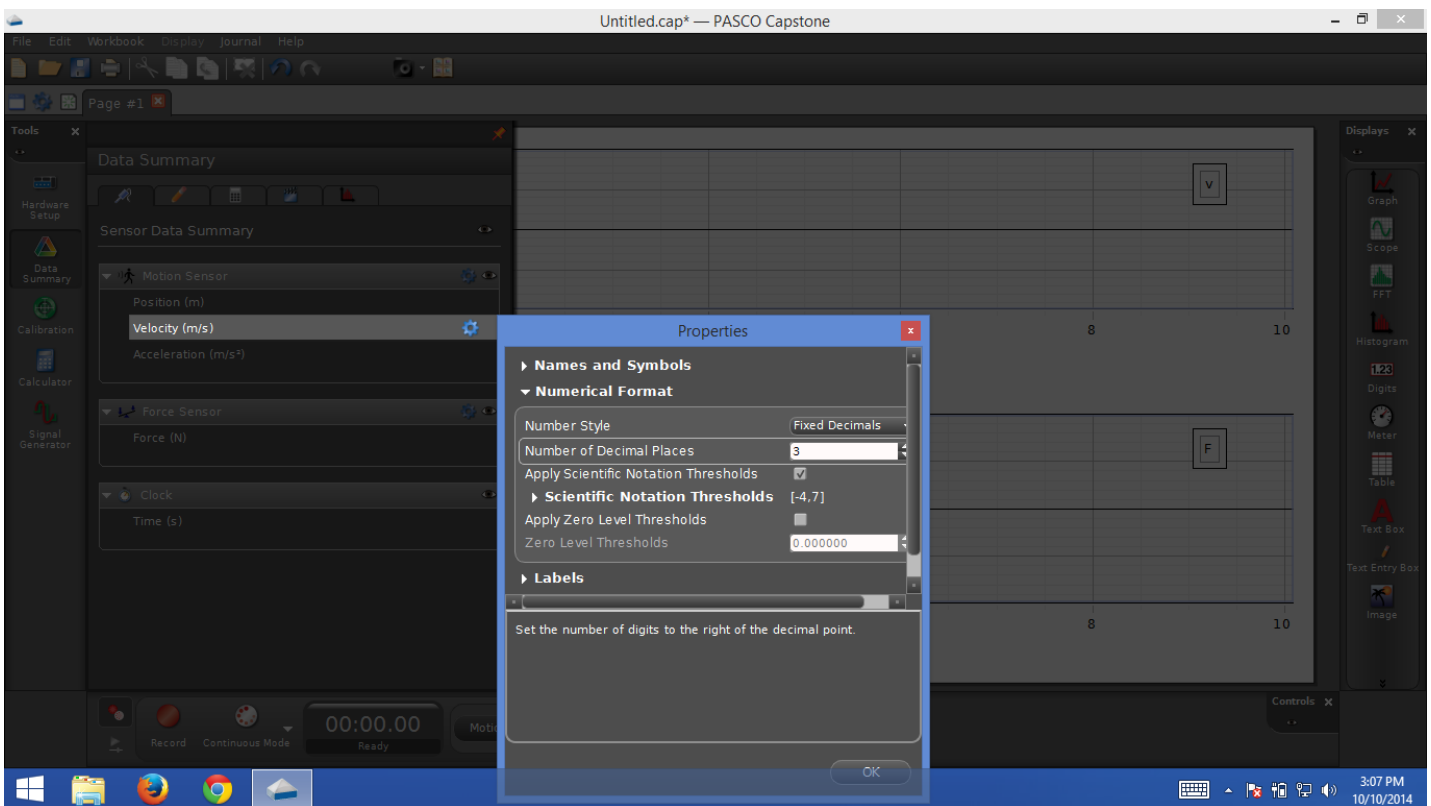
**Free-body diagram**



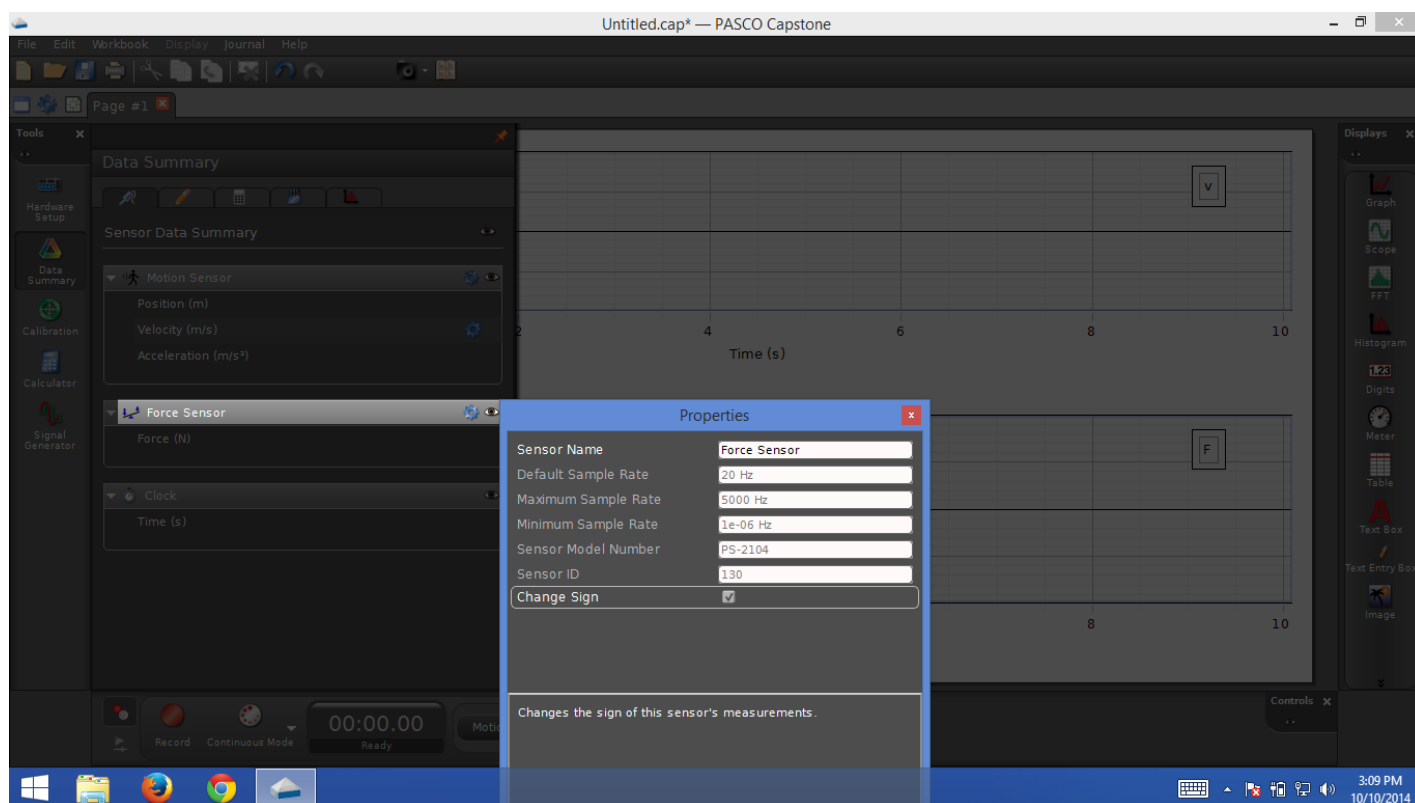
2. Prediction: Draw lines on the velocity, acceleration and force graphs below predicting the shapes of the curves for the cart after being released.



**Setting up the Sensors and Capstone:** Connect the motion and force sensors to the PASCO interface box. 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. 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. See instructor if you need help with this.



We also need to change the sign of the force sensor so that the positive directions of the force and motion sensors are the same. 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:** Place the cart on the track about 30 cm (1 foot) away from the motion detector with one person holding it in position. You will need to zero the force sensor, before each run. To do that you need to push and hold the zero button on the sensor for a few seconds but you will need to do that with no force acting on the sensor. So you will have to make the string go slack before you zero the sensor. Have another team member start taking data. Let go of the cart as soon as the clicking sound is heard, careful to not get any hands between the detector and the cart. Make sure that cord connecting the force sensor to the PASCO interface is not inadvertently messing up your data. Do this by picking up the cord a couple feet from the sensor so that the cord is slack between your hand and the sensor and is not rubbing on the table or anything else. As the cart moves towards the end of the track, move your hand with it so that the cord remains slack the whole time it is in motion. This is especially important for the first few runs. Catch the cart just before it crashes into the other end of the track.

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 direction of the acceleration and the direction of the force the same? 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. Do this by selecting 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 using the summation sign sigma, “ $\Sigma$ ”. When you select, choose data only for the appropriate portion of the experiment when the situation is 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 in the appropriate row of table 1 below

**Average Force = \_\_\_\_\_**

**Average Acceleration = \_\_\_\_\_**

Remember there are units for each of these quantities.

**After labeling the three graphs, copy and paste them to a Word document.**

10. **More Experiments:** Your task is to figure out the value for the acceleration of the cart for different tensions of the string. Tension of the string can be changed by adding different masses onto the hanger. Change masses on the hanger and repeat, remembering to zero the force sensor with the string slack before each run. Record the average force (tension of the string) and the average acceleration for each added mass in the table above. You already found the data for Hanger + 20 g in Question 9. Now complete the rest of **Table 1**.

<b>Table 1</b>	Magnitude of Force (N)	Magnitude of Acceleration (m/s <sup>2</sup> )
Hanger + 10 g		
Hanger + 20 g		
Hanger + 30 g		
Hanger + 40 g		

**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 points and re-do that run to check your data. The most common causes of error are forgetting to re-zero the force sensor while the string is slack before each run, not keeping the force sensor cord slack during the entire run, or failing to select data while the cart is freely moving.

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?
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 and the force sensor).
- Mass = \_\_\_\_\_
15. How does your slope compare to the mass of your system?
16. Summarize the relationship between force, mass, and acceleration you found from your data.

**Part B: Mass and Acceleration**

17. Now we want to repeat the experiment keeping the force constant and changing the mass of the cart. 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 2	Mass (kg)	Acceleration (m/s <sup>2</sup> )	Force (N)
Cart and force sensor			
Cart, sensor & 250 g			
Cart, sensor & 500 g			
Cart, sensor & 750 g			
Cart, sensor & 1000 g			

Copy the acceleration and mass data from your table into Excel. Then create a graph of acceleration vs. 1/mass. Is your graph a nearly straight line? If not, pick out the most suspicious data points 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.

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

**Instructions on how to submit the graphs:**

1. Open a word document and type the names of all present group members.
2. Paste labeled graphs of velocity, acceleration, and force vs. time from first run in Part A.
3. Paste force vs. acceleration graph with fit line from Part A.
4. Paste acceleration vs. 1/mass graph with fit line from Part B.
5. Please be smart about formatting of the Word document so you don't waste paper.
6. Print your Word document and staple it to you lab write-up.