LAB 5: FORCE AND MOTION - NEWTON'S LAWS(TPL1)

Objectives

- The relationship between force and acceleration when the acceleration is not constant
- How to produce motion with a constant acceleration
- The relationship between force and constant acceleration

Web pages that might be useful:
Online help page for this lab, Graph layout

Introduction If you apply a large enough force on an object--like a cart on a table--you can get the object to move with an increasing velocity--with acceleration. The acceleration acts in the direction of the net force acting on the object. You will use both the force probe and the motion detector to compare the acceleration of the object with the force on the object. This will initially be a non-constant force, thus, a non-constant acceleration. You will also investigate what sort of net force applied to an object causes a steadily increasing velocity--a constant acceleration

Preliminary activities

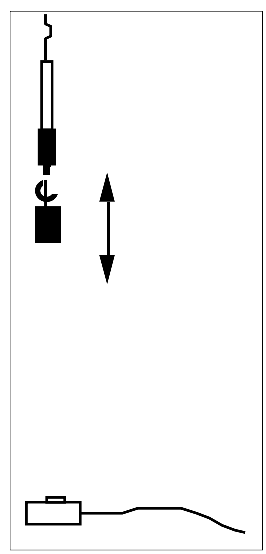
1. Prepare equipment. Connect the motion and force sensors through USBLink, and then to the laptop. It would be very helpful to look at the Online help page for this lab. Start the DataStudio software.

2. Load the experiment file. Download the DataStudio file **`Lab05_ForceMotion.ds`** from the lab schedule webpage, and open it in DataStudio.

3. Prepare the force probe. Press the ZERO button on the side of the probe (this is a "mechanical" tare for the probe). We can't "zero" the probe in DataStudio, so occasionally we might need to keep track of a zero "offset" and account for it**.**

Part 1 Force and Acceleration

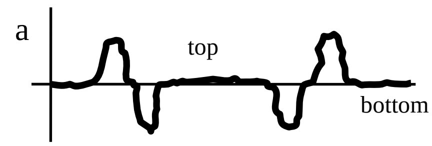
In this activity you will apply a varying force to an object, and examine the acceleration this force produces.



1. Set up the motion detector and force probe. Place the motion detector on the floor (or on a stool) in a position where you can hold a mass connected to a force probe directly above it. If possible, protect the motion detector with a plastic cage.

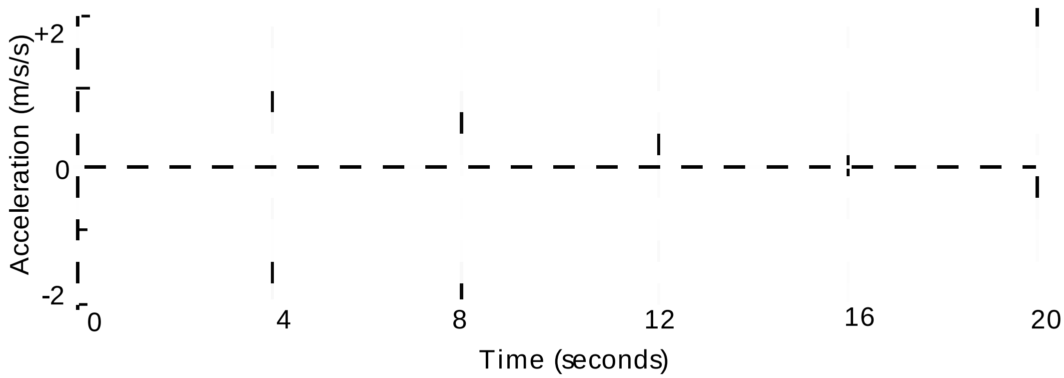
2. Prepare mass. Hang a 200-gram mass from the force probe, and use a small piece of tape to secure it to the hook so that it will not fall off or "wiggle" around. Tape the cardboard square to the bottom of the hanging mass (makes a cleaner "target" for the motion detector).

3. Prepare to graph acceleration only. Double-click the "Acceleration Only" graph to make it active. Make sure the screen shows one graph of Acceleration vs. Time – with a timescale of about 20 seconds. See the graph layout help page for information on how to make these changes in DataStudio. (You may need to change the sampling options for the "automatic stop".)



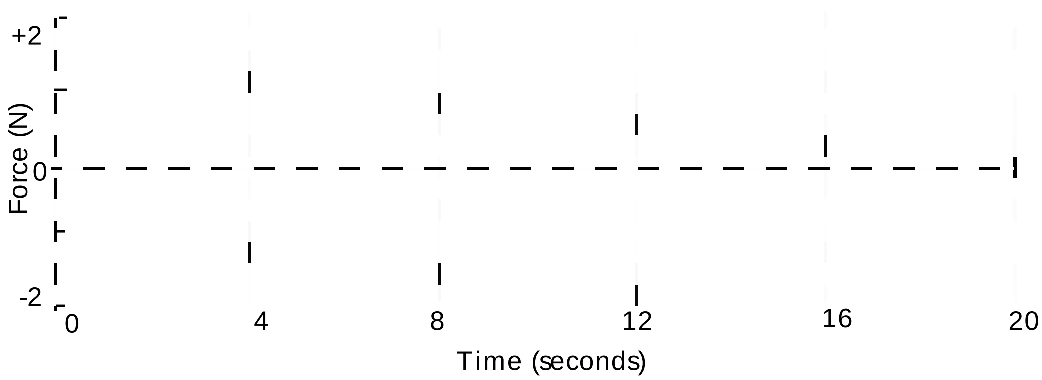
4. <u>Start graphing.</u> Hold the force probe and mass steady for the first several seconds. Then pull the probe up away from the motion detector a short distance, stop, and then move it a short distance down closer to the motion detector. Hold it steady for several seconds more and then repeat this motion. (Up smoothly and rapidly, stop, down smoothly and rapidly, stop, etc.) A sample is shown to the right :

5. <u>Sketch the acceleration.</u> Sketch the acceleration graph on the axes shown below. Do not display the force graph yet.



Motion of a mass hanging from force probe – moving up and down

Prediction On the force axes below, sketch with a dotted line your prediction of the force that could have caused the acceleration of the mass shown above.



Prediction of Force graph for vertically moving object

6. <u>Display the force and acceleration.</u> Change the screen to display two panes – Force vs. Time and Acceleration vs. Time. Sketch the force graph with a solid line on the axes above.

Questions Answer these on the Data/Question sheet:
a) Did the force graph agree with your prediction? In what ways did it agree and disagree?
b) Compare the acceleration and force graphs. Are they similar in shape? Is this what you would expect based on Newton's Second Law?

Part 2 Speeding Up a Cart Steadily - Constant Acceleration

Prediction Suppose that instead of making the cart move at a constant velocity, you want it to speed up steadily (with a constant acceleration). Describe in words below and sketch the velocity, acceleration and force graphs that you would expect.

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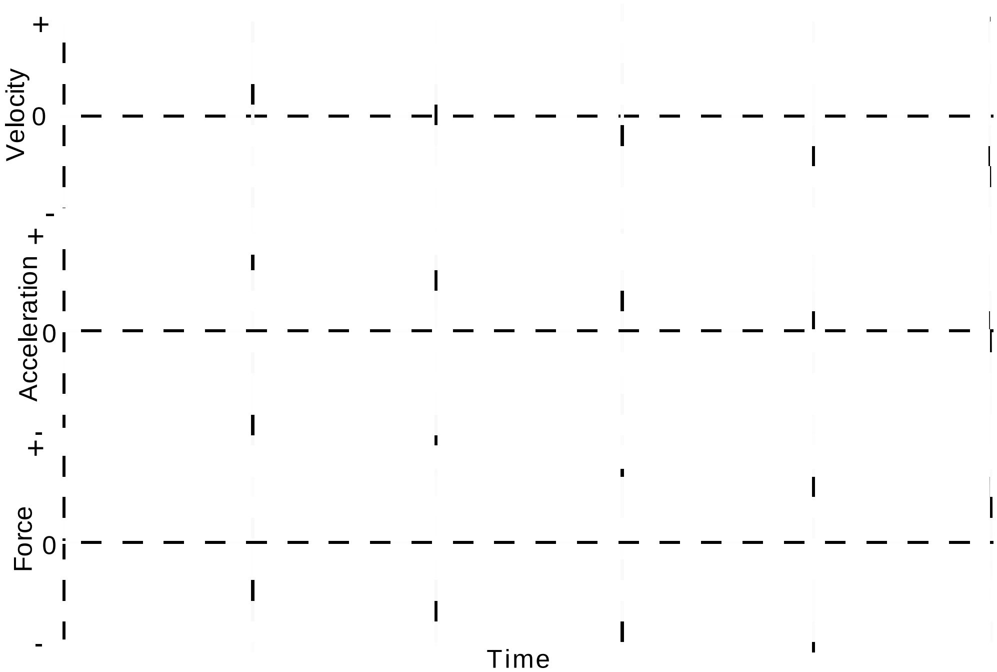
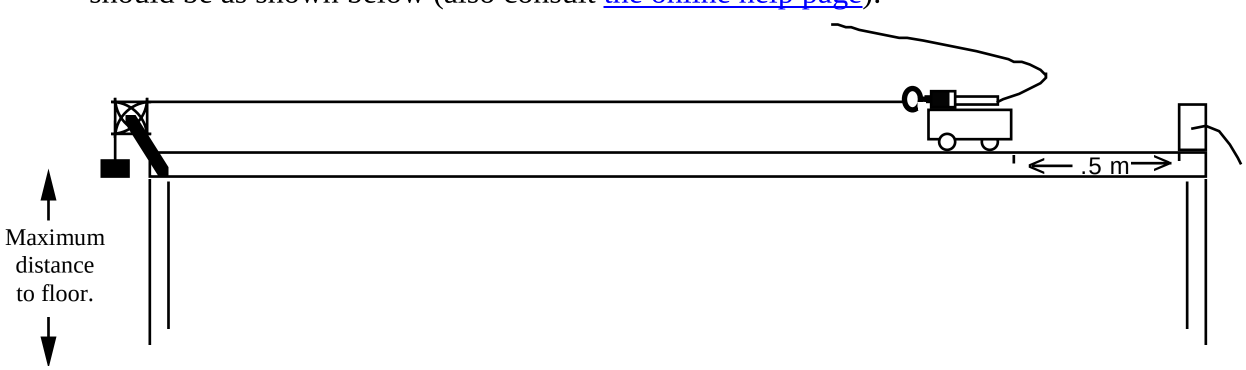


Motion predictions for constant acceleration of cart on track

Test your predictions as follows:

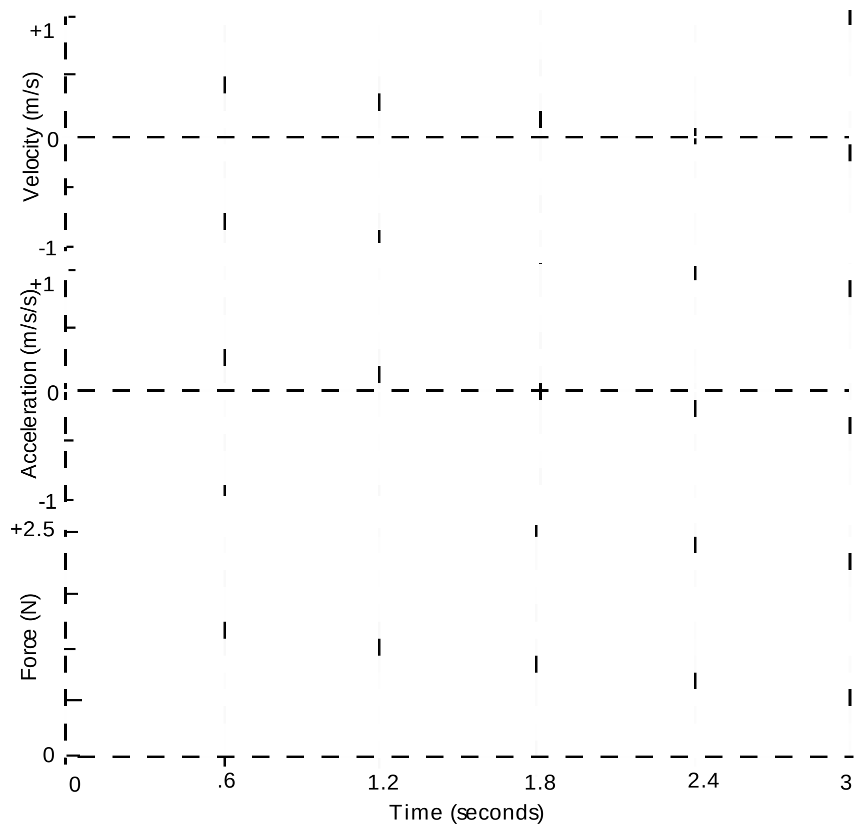
1. Initial setup. Set up the ramp, pulley, cart, string, motion detector and force probe. The setup should be as shown below (also consult the online help page):



Cart, force probe, and motion detector assembly

2. Prepare probe. Be sure that the force probe wire is out of the way of the motion detector. You may have to hold the ***force probe cable*** up off the table and "follow" the cart as it moves down the track, when you are graphing ... to eliminate any extra drag on the cart (but don't "pull" or "slow down" with the wire!).

3. Prepare to graph velocity, acceleration and force. Double click on the "Force Accel Velocity" graph, You may want to save your data as backup and then clear the old data from any previous graphs by going to the Experiment menu and selecting "Delete All Data Runs".



Motion of a cart with constant acceleration

4. Prepare hanging mass. Hang 50 grams from the end of the string over the pulley. Place your fingers in front of the cart (at the force probe hook end) so that it cannot move. The back of the cart must be at least 0.5 meters from the motion detector.

5. Start graphing. Click the START button to start graphing. Release the cart **after** about 1-2 sec (wait for the "ticking" sound -- that means the detector is "on"). We **want** to graph a moment of the "stopped" cart! Be sure that the motion detector is seeing the cart during its complete motion. Repeat until you get good graphs. [Catch the cart at the end before it hits -- this will reduce harmful vibration to the force probe.]

What is a "good graph"? We are looking for a nice constant acceleration curve, and a constant force curve. [Note, the two are not necessarily related to each other, since the acceleration curve comes from the motion detector, and the force curve comes from the probe.] Be patient with the data taking, and try to capture as large a region as possible for constant acceleration and constant force.

Also, note: we want to have a segment of data recorded (about 1-2 seconds) BEFORE the cart starts moving. This way we can compare the force before the motion to the force after the cart is moving.

6. Sketch final graphs. Adjust the scales if necessary to display the graphs more clearly. Sketch the actual velocity, acceleration and force graphs on the axes above. Draw a "smoothed" force and acceleration graph; don't worry about small bumps or erratic artifacts.

7. Save and annotate data. Rename the data (for comparison with later events) and annotate it if you wish. There is information about how to rename the data in the "store and examine" help page. You might want to rename that data run to be "50light" – to indicate 50-gram hanging mass with light cart.

Questions Answer questions on the Data/Question sheet for Part 2.7

Part 3 Accelerating with a Larger Force

In this activity you will examine the acceleration of the cart with a larger applied force than in Part 2. [SAVE YOUR DATA AT THE END OF THIS ACTIVITY – and, you will be printing a graph.]

Prediction If you double the force applied to the cart, what will happen to its acceleration? Will it still be constant? How large will it be?

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1. Prepare cart. This time we will accelerate the cart with a 100-gram hanging mass. Be sure that the cart begins at least 0.5 meter away from the motion detector, and that the force probe cord is out of the way. Repeat as necessary to get decent graphs. (Again, graph the first few seconds of no motion!)

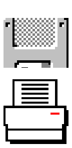
2. Sketch graphs. Sketch your graphs with a dashed line on the axes on the previous page.

Questions Answer on the Data/Question sheet:

a) Did your force graph for the larger applied force agree with your prediction? Explain any differences.

b) How does the acceleration of an object seem to depend on the net force applied to the object?

3. Measure the average forces and accelerations. Using the mouse – select a data run, and highlight a constant-force region of both data sets (this would be the horizontal parts of the force graph after the initial "dip" once the cart starts moving). Make sure the "mean" is displayed in the graph legend and find the mean value of the force and the acceleration for each of the two data runs. Record these mean values on the Data/Question sheet.



4. Save data and print. Make sure you have saved a copy of these two sets of data (50 grams in the background data set, and 100 grams in the "latest" set). Print the graph window (all the panes). [See the Printing in DataStudio help page.] Store this "latest run" data, and rename it to "100light". For the next section, you could hide the 50light dataset (see the store/examine help page for assistance in hiding/renaming datasets).

Questions Answer questions on the Data/Question sheet for Part 3.4.

Part 4 Accelerating a More Massive Cart

Prediction If the cart's mass were larger than before, and you accelerated it with the same 100-gram hanging mass, would the acceleration be different, and if so, in what way?

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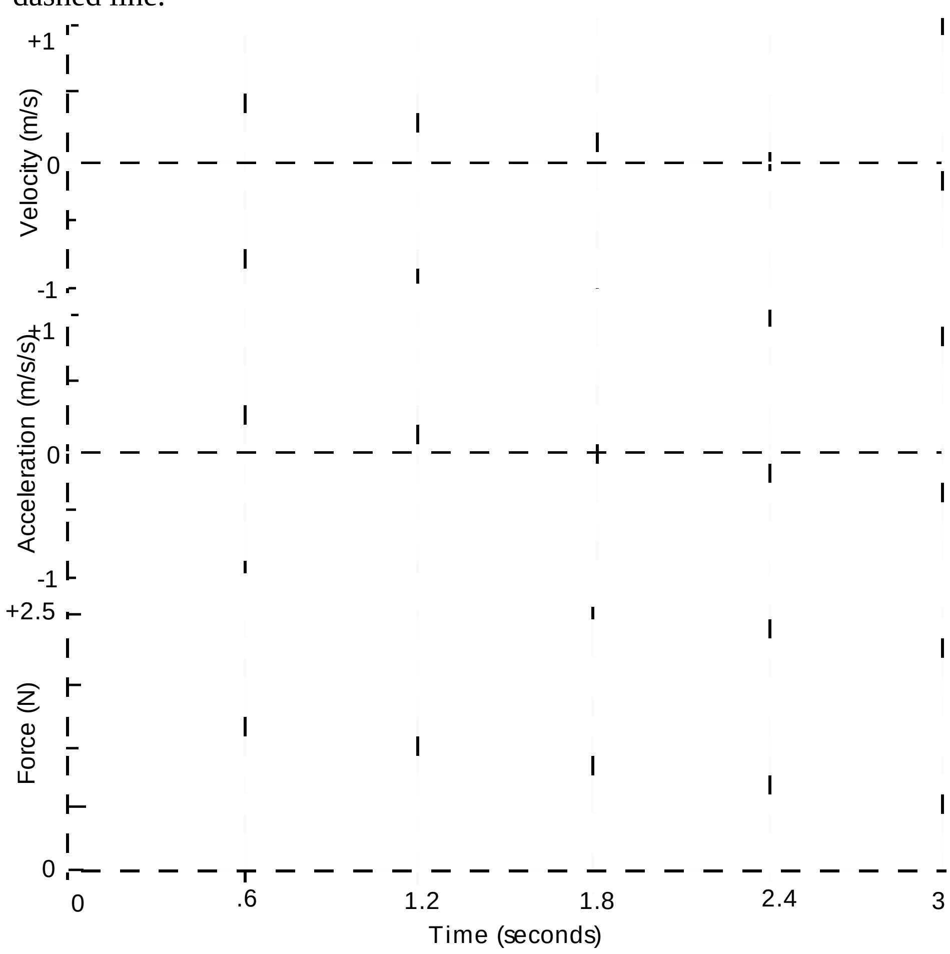
Test your prediction.

1. Mass of cart. Measure the mass of the cart including the force probe: _________ kilograms

2. Bar masses. Measure the mass of the two bar masses: ___________ kilograms

3. Total mass. Add the two bar masses on top of the cart.
New mass of cart: __________ kilograms.

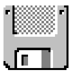
4. Accelerating the cart. Accelerate the cart with the 100-gram mass. Repeat until you get good graphs. Sketch your graphs on the next page. Also sketch the graphs for the less massive cart with a dashed line.



Motion of a less massive or more massive cart, with the same hanging mass

5. Record values from your graph. Find the mean values using the mouse and graph legend and record them on the Data/Question sheet. Rename this dataset as “100heavy”.

6. Combine this data with the previous data. These values can be compared with those from Part 3 for the lighter cart accelerated with the same 100-gram hanging mass. Record both sets of values in the table on the Data/Question sheet.



Calculate the ratios of force to acceleration, and record in the table. Save your experiment file from this section (“50light” is hidden, and both “100light” and “100heavy” are showing). Print the graph window (with all the panes) [see Printing help page].

Questions Record answers on the Data/Question sheet.

a) Do your graphs agree with your predictions? Explain any differences.

b) Does a mathematical relationship appear to exist between acceleration and mass for an object pulled with a constant force, and if so, what is it? Justify your answer using the data in your table.

c) Look at the force graphs again. When you let go of the cart (several seconds after the graph starts), there is a “dip” in the force graph. Explain why the “dip” is there – also, in which graph is it the most noticed (why?).

DATA/QUESTION SHEET FOR LAB 5: FORCE AND MOTION - NEWTON'S LAWS

Part 1 Force and Acceleration

Questions

a) Did the force graph agree with your prediction? In what ways did it agree and disagree?

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b) Compare the acceleration and force graphs. Are they similar in shape? Is this what you would expect based on Newton's Second Law?

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Part 2 Speeding a Cart Up Steadily - Constant Acceleration

Questions a) What kind of force is needed to move the cart with a steadily increasing velocity--constant, increasing or decreasing? (Look at the force on your graph during the time that the cart is accelerating.) Is this what you expected-- does the force graph agree with your prediction?

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b) Does the acceleration graph agree with your prediction? What kind of acceleration corresponds to a steadily increasing velocity?

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c) Compare the force applied to the force probe by the hanging mass during the 1 second that the cart was at rest and during the time when the cart was accelerating. Is one of these forces larger? Try to explain. (Hint: Remember that the force probe is measuring the tension in the string and not the weight of the hanging mass.) [This effect is sometimes hard to see.]

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Part 3 Accelerating with a Larger Force

Questions a) Did your force graph for the larger applied force agree with your prediction? Explain any differences.

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b) How does the acceleration of an object seem to depend on the net force applied to the object?

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3. Measure the average forces and accelerations.

Record the mean values in the table below:

	Applied Force (N)	Acceleration (m/s^2)	Mass ratio: Force/accel.
50 grams			
100 grams			

Questions c) Does a mathematical relationship appear to exist between the force probe reading with 50 grams and the force probe reading with 100 grams, if so, what is it? Use the data in your table to justify your answer.

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d) Does a mathematical relationship appear to exist between the acceleration with 50 grams and the acceleration with 100 grams, and if so, what is it? Use the data in your table to justify your answer.

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e) Calculating the mass: [Note, since there are two different probes, this relationship may not show up as well as the previous two.] Does a mathematical relationship appear to exist between the mass ratios for these two cases, and if so, what is it? What *should* it be?

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Part 4 Accelerating a More Massive Cart

Record your data from this section:

mass of the cart including the force probe: __________ kilograms
mass of the two bar masses: ____________ kilograms
total mass of cart: ___________ kilograms.

5. Record values from your graph. Find the mean values using the Statistics tool, and record them here:

Larger Mass Cart **Mean force** (N): _____

Mean acceleration (m/s^2): ____

6. Combine this data with the previous data. These values can be compared with those from Part 3 for the lighter cart accelerated with the same 100-gram hanging mass. Record both sets of values in the table below:

Total Mass of Cart (kg)	Applied Force (N)	Acceleration (m/s^2)	Ratio: Force/Accel (mass)

Calculate the ratios of force to acceleration, and record in the table. Save your experiment file from this section ("50light" is hidden, and both "100light" and "100heavy" are showing). Print the graph window (with all the panes) [see Printing help page].

Questions a) Do your graphs agree with your predictions? Explain any differences.

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b) Does a mathematical relationship appear to exist between acceleration and mass for an object pulled with a constant force, and if so, what is it? Justify your answer using the data in your table.

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c) Look at the force graphs again. When you let go of the cart (several seconds after the graph starts), there is a "dip" in the force graph. Explain why the "dip" is there – also, in which graph is it the most noticed (why?).

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Questions/Suggestions -> James Nolta - Nolta@LTU.EDU