Exploring The Relationship between Force, Mass, and Acceleration

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Introduction

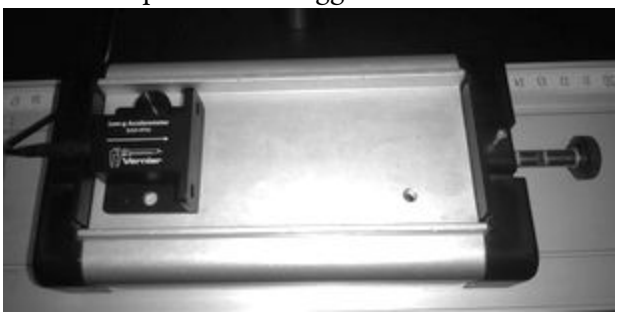
Newton's second law states that the acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object. That is,

$$F = ma\,.$$

This lab is designed to explore this relationship between mass and acceleration in systems with multiple objects of multiple weights.

Materials and Apparatus

- Scale or balance
- Dynamics cart and track
- Various known weights
- Pulley and mount for track
- Vernier Low-g Accelerometer (2) and screw to secure
- String
- Clamps)
- Vernier LabPro
- Computer with Logger Pro



Procedure

Part I: Setup and Initial Measurements

1. Assemble the equipment as shown on left. Use clamps to secure the track.
2. Plug the accelerometer into the LabPro and connect the LabPro to the computer. Ensure all components are powered and turned on. Open Logger Pro on the computer and the system should automatically detect the LabPro and Low-g Accelerometer - if not, ask your teacher for help.
3. Tie a string to the front of the dynamics cart and thread it over the pulley so that it hangs downward. Adjust its length so that it does not come off the pulley when the cart is pulled back, and that it does not touch the ground when the cart is pushed all the way forward. Tie a loop at the end of the string to attach the weight.
4. Measure the mass of the cart, including the mass of part of the cord from the accelerometer and the string.

Why do we measure the mass of the cart with the accelerometer and string, instead of without?

5. Hook the weight to the loop.

Part II: Changing the force exerted on the cart

1. Attach a small weight to the string.
2. Pull the cart back as far as it can go on the track without causing the mass on the string to lift above the edge of the table.

What will happen when the cart is released? Why?

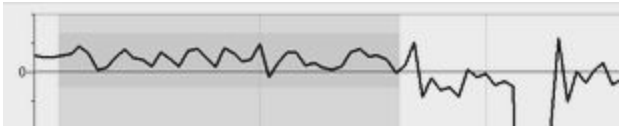
3. Begin recording data in Logger Pro and release the cart.
4. Select the part of the acceleration which is the most stable and find the mean acceleration (see note). Make a note of the value, as well as the mass used, in another application, such as Google Sheets.
5. Repeat data collection (2-4) for three more increasingly massive weights.

Part III: Changing the mass of the cart

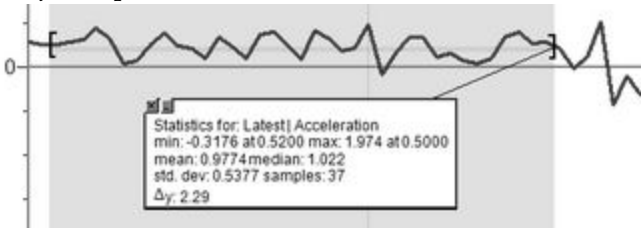
1. Attach the smallest weight to the string.
2. Place a small weight on the cart.
3. Again, pull the cart back as far as it will go.
4. Begin data collection in Logger Pro and release the cart.
5. Select the part of the acceleration which is the most stable and find the mean acceleration (see note). Make a note of the value, as well as the mass used, in another application, such as Google Sheets.
6. Repeat data collection (3-5) with increasingly massive weights on the cart. Do not change the weight at the end of the string.

A Note on Data Collection

Once you have an appropriate data collection in Logger Pro, you will need to copy the data into a spreadsheet before performing the next data collection. First, select a portion of the data which seems to average to a relatively flat line.



Now, go to `Analyze → Statistics`. Note the **mean** given—this is the value you will want to copy into your spreadsheet.



Calculations and Questions

1. In your own words, explain and summarize Newton's Second Law.
2. What happened to the acceleration as the weight of the mass at the end of the string was increased? Why? How is this consistent with Newton's Second Law?
3. Calculate, for each trial in the first set (changing weight on string) the force exerted on the weights by gravity. Use $F = ma$ where $a = g = 9.8\ m \cdot s^{-2}$.
4. Create a graph plotting acceleration of the cart against force exerted by gravity. What do you notice?

What causes the force on the cart? Is it gravity? If so, how is gravity, a vertical force, transformed into the horizontal force applied to the cart? Is this transformation optimally efficient? How could energy be lost?

5. Calculate the theoretical, or ideal acceleration on the cart for each trial. Use $F = ma$ where F is the force previously calculated and m is the mass of the cart **added to the mass of the weight**.
6. Calculate the percent error for each trial. Use the formula:

$$\%\ Error = \left|\frac{Theoretical\ Value - Experimental\ Value}{Theoretical\ Value}\right| \times 100\%$$

7. What happened to the acceleration as the mass of the cart was increased? Why? How is this consistent with Newton's Second Law?
8. Calculate the force exerted on the weight by gravity in the second set of data (changing the mass of the cart). You only need to perform this calculation once, as the weight was always the same.
9. Calculate the total mass of the cart for each trial by adding the mass of the cart (with sensors, string, etc.) and any additional weights used.
10. Create a graph plotting acceleration of the cart against mass of the cart? What kind of relationship do you expect? Is this what you observe?
11. Calculate the theoretical, or ideal acceleration on the cart for each trial. Use $F = ma$ where F is the force previously calculated and m is the total mass of the cart **added to the mass of the weight**.
12. Calculate the percent error for each trial using the formula above.

Note: You can use the spreadsheet to perform these calculations, but please include at least one sample calculation in your write-up.

Include in Your Lab Write-Up

Title Page (1)
Including name, date, and class period.

Purpose (1)
Explain the goal of the lab.

Apparatus & Setup (2)
List all materials used and include a diagram of equipment setup.

Procedure (4)
Explain the procedure so that someone else could reproduce the experiment.

Data
Create two separate tables, one for each part of the lab. Additionally, note the mass of the cart.

Questions and Calculations
Answer all questions completely, and provide at least one example for every calculation. Include any graphs created.

Conclusion
In your conclusion, discuss the purpose of the lab, how you fulfilled that purpose, describe your results/findings, and detail at least one new thing you learned.

Discussion of Results
Discuss sources of error and uncertainty in the lab and equipment used.

Grading Rubric

	4 points	3 points	1 point
Data	Data were collected properly, and are meaningful and correct.	Data were generally collected properly and for the most part are meaningful and correct.	Procedure was not followed; data are not meaningful or seemingly random.
Graph	Graphs are made correctly with a title and correct labels. Interpretation of graphs is correct as well.	Graphs are nearly correct OR interpretation of graphs is nearly correct.	Graphs are made incorrectly and interpretation of graphs is weak or nonexistent.
Calculations & Questions	All calculations are carried out correctly; questions are answered correctly.	Calculations are nearly all correct; some answers may not be fully correct.	Calculations or answers to questions are repeatedly incorrect.
Conclusion	Conclusion contains required components and correctly interprets findings.	Conclusion contains required components and interprets findings.	Conclusion does not contain required components, or does not make a meaningful attempt to interpret findings.
Discussion of Results	Discussion of Results describes and explains multiple sources of error.	Discussion of Results describes and explains a source of error.	Discussion of results does not explain any sources of error.
Concepts	Student displays and is able to effectively communicate a clear understanding of the concepts behind this lab.	Student displays a moderate understanding of the concepts behind this lab.	Student displays a very weak understanding of the concepts behind this lab.

_____ /32 points