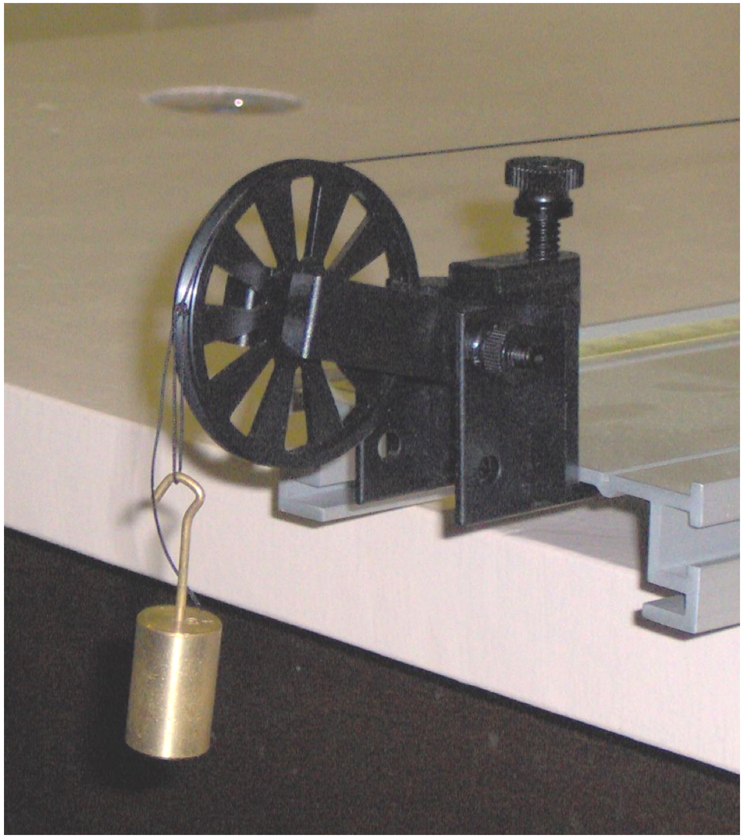
Force and Acceleration



Introduction

Newton's second law states that:

The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass

$$\vec{a} \propto \frac{\sum \vec{F}}{m}$$

Which may be rewritten as

$$\sum \vec{\boldsymbol{F}} = m\vec{\boldsymbol{a}}$$

Introduction

For a system of connected masses, such as is pictured below (Diagram 1), the magnitude of the acceleration of each mass is the same.

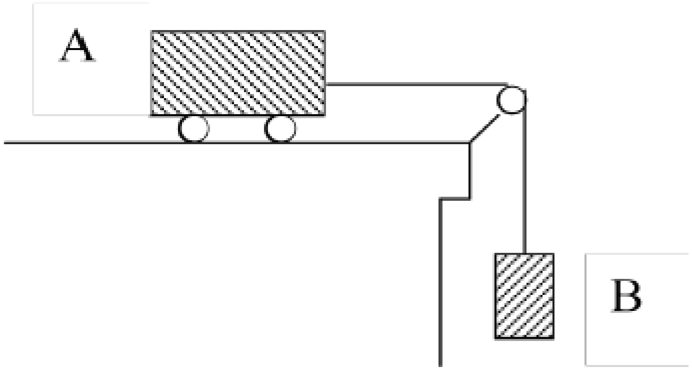


Diagram 1: Sketch of the system.

Introduction

Applying Newton's Second law to each of the masses, we obtain the result

$$W_B = (m_A + m_B)a + f$$

Where W_B is the weight of mass B. The symbol m_A represents the mass of the cart and its contents, m_B is the hanging mass and f is the resistive force (friction).

Objectives

In this experiment, you will investigate Newton's second law by using a system of connected masses.

You will use the motion detector to determine the acceleration of the system.

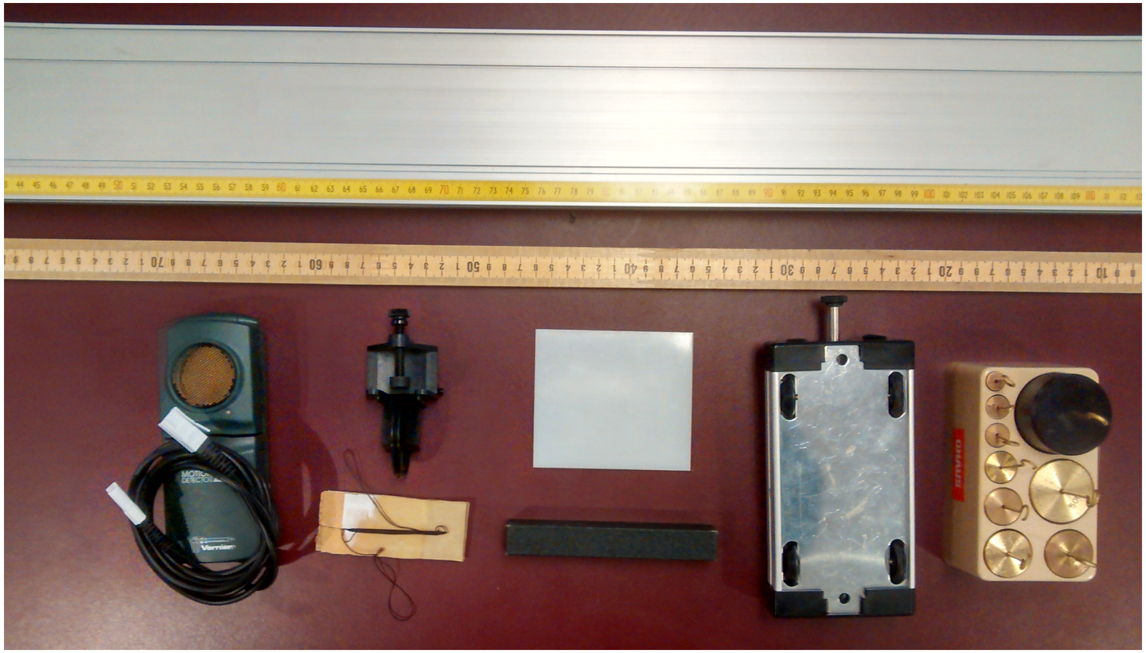
You will employ unit analysis method to find the meaning of the slope of the graph of weight of the falling mass vs the acceleration of the system.

You will compare your experimental results with the Newton's second law theory analysis.

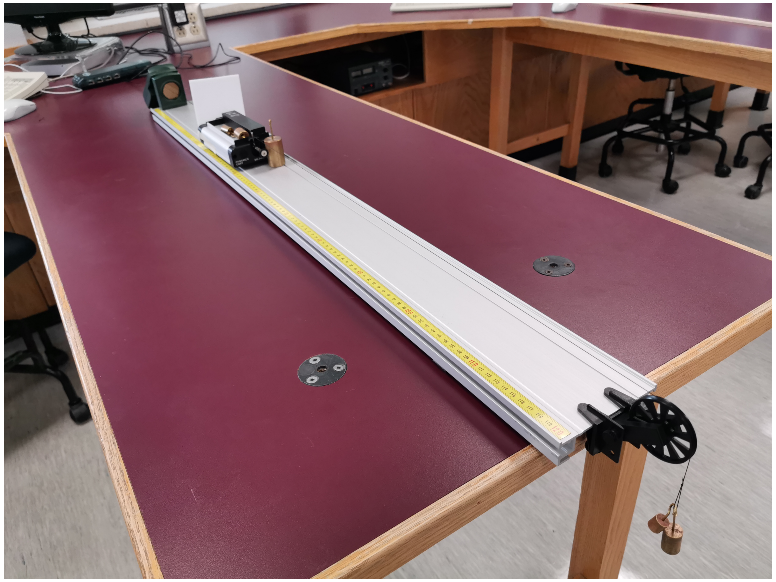
Equipment List

You have been provided with:

- Track
- Cart
- Block
- Pulley
- String
- Card
- Motion sensor
- Mass set
- Metre stick



Setup: equipment assembly



Setup your experiment:

- Place the track with the unblocked end protruding slightly past the edge of the bench.
- Place the cart on the track.
- Attach the pulley to the free end of the track and run the string from the cart over the pulley.
- Place the black block in the cart.
- Tape the plastic card to the end of the cart making sure it isn't low enough to touch the track.
- Put the 50 g mass and one of the 20 g masses in the cart (lying sideways). Hang the other 30 g (the 10 g and one of the 20 g) masses from the end of the string.
- Plug the motion detector into DIG/SONIC 1 on the LabPro and place it at the end of the track.

Setup: equipment assembly

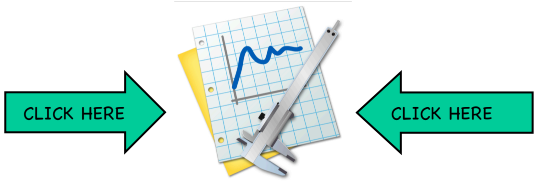
Check your setup:

- Is the track level?
  - Check the levelling by pushing the cart gently left and right to test if it rolls downhill one way or the other. Adjust the levelling screw as needed.
- Is the string level?
  - Use a metre stick to make sure the string is exactly parallel to the track. The level of the pulley wheel can be adjusted by first loosening the screw at the side.
- Is the string too long?
  - When the cart at the end of the track closest to the pulley, the hanging mass **should not** be touching the floor. Shorten the string if necessary.

Data collection

QUESTION 1: As the falling weight increases, what happens to the acceleration?

- Click on the icon to open Logger Pro



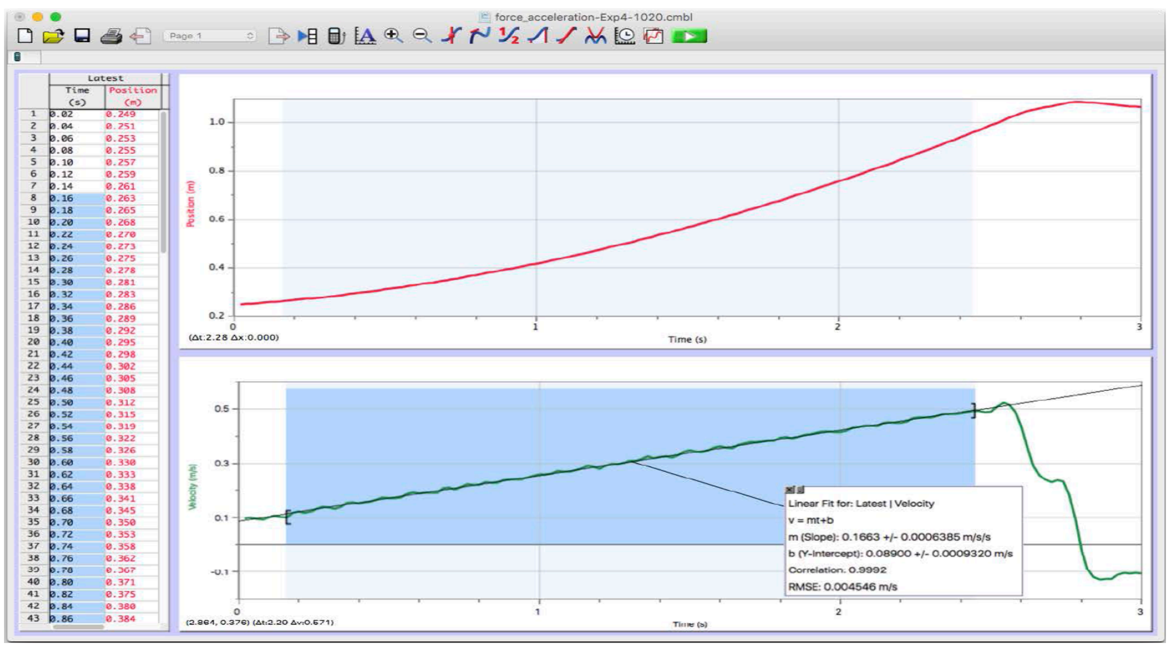
- You should see two graphs on the screen:
  1. position vs time,
  2. velocity vs time.

If *Logger Pro* does not contain these graphs, consult an instructor.

- Click collect and release the system. Be sure to catch the cart before it hits the pulley.

Data collection

- Activate the velocity vs time graph by clicking on it.
- Highlight the **linear portion** of the velocity vs time graph as shown below. The acceleration of the system is the slope of this part of the graph. Use **Analyze/Linear Fit** function in Logger Pro to obtain this.
- Enter the acceleration in the first line of **Table 1**.



Data collection

In the first row of **Table 1** also:

- record the value (in kilograms) of the falling mass,
- calculate and record the weight of the falling mass ($W = mg$ with m in kg and $g = 9.81\ m/s^2$).

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CP

Have an instructor check the first data set for a reasonable value of a.

!

- Exchange the masses so that you have $40.0\ \mathrm{g}$ as the falling mass, and $60.0\ \mathrm{g}$ on the cart. (The total mass of the system stays constant!)
- Run the experiment again. Record the data in your laboratory workbook.
- Do five more runs with $50.0\ \mathrm{g}$, $60.0\ \mathrm{g}$, $70.0\ \mathrm{g}$, $80.0\ \mathrm{g}$ and $90.0\ \mathrm{g}$ as the falling mass, with the total mass constant.
- Record your data in your laboratory workbook **Table 1**.

LW

Analysis

We will analyze our data using Graphical Analysis software. Open it by clicking on the icon below.

In Graphical Analysis, plot the **weight** of the hanging mass versus the **acceleration** of the system by using Table 1 data.

In Graphical Analysis, click **Analyze** then **Linear fit**.

Double click the pop-up box and turn on **Show Uncertainties**.

Enter the slope and its uncertainty in **Table 2**.

Enter the y-intercept and its uncertainty in **Table 2.**

Title your graph and label your axes.

Print your graph and staple it to your report.

Analysis

QUESTION 2 : From the weight vs acceleration graph, What are the units of the slope? Then do a unit analysis to break this unit down to a simpler unit. Please use SI units.

Use a lab balance to weigh the cart, the card, the string and all the masses.

Place the cart upside down on the balance so it doesn't roll off.

Enter the mass and its uncertainty in **Table 3**.

QUESTION 3: Compare Table 3 value to the value of your slope. What physical quantity do you think the slope corresponds to?

QUESTION 4: What are the units of the y-intercept?

Analysis: Theory

- **Click here to follow the process of drawing the free body diagrams and writing the Newton's second law equations for each mass.**
- **(link to P1020-lab4-NII-treatment.pdf)**
- **The information in this file will help you answer questions 5 & 7.**

Analysis

QUESTION 5: By comparing the equation

$$W = (m_a + m_b)a + f$$

with the equation of a straight line

$$y = mx + b$$

what physical quantities do the slope and intercept of your graph represent?

QUESTION 6: Is this answer consistent with your answers to questions 3 and 4? Explain.

QUESTION 7: Compare the value of frictional force you just found with the weight of the smallest $30g$ falling mass. Is the frictional force f smaller, bigger, roughly the same? Is this expected? HINT: What would happen if these two values were interchanged?

Summary and Conclusion

Q

QUESTION 8: Identify two sources of uncertainty in this experiment. Are these random or systematic?

Q

QUESTION 9: Newton's second law states that the acceleration of an object will increase if the net force on it is increased. Did you observe this to be true? Explain.

!

- **Disassemble lab setup. (You will lose marks otherwise!)**
- **Close all applications on computer and log out.**
- **Submit your laboratory workbook with your graph attached.**