Name: ____________________________________

LAB 6. TENSION AND LINKED MASSES

Introduction

This lab involves two data sets, one of which you measured last week. The other is a classic Atwood machine with two masses connected by a string over two pulleys.

Supplies

Atwood machine: board with one standard pulley and one smart pulley, two mass hangers with masses, Capstone data setup, pads for the floor
Rail cart: data from last week

Atwood Machine Data Collection

In the experiment, the heavy mass falls, lifting the light mass until the heavy mass lands on the floor. You will measure the acceleration of the masses as they move.

Each hanging mass has a fixed mass and several movable masses. Initially, the light side has two 20-g masses and one 10-g mass. The heavy side has one 50-g mass and one 5-g mass. You will transfer mass from one side to the other, keeping the total mass constant.

When the falling mass hits the ground, the rising mass may continue moving upward. It is best if a student is ready to catch the rising masses after the falling mass lands on the pad.

1. Place pads under both pulleys. There should be more padding under the heavier weight.
2. Run the string over the two pulleys. Hang the hooks of the mass hangers through the loops at each end of the string.
3. Lower the lighter mass so that it is near the floor.
4. Start data collection.
5. Release the masses so that the lighter mass is pulled upward by the falling heavier mass. Catch the rising lighter mass after the falling mass hits the floor.
6. Stop data collection.
7. Make a velocity-time graph of the run. Fit the linear (constant-acceleration) portion of the graph to a linear fit. The slope of this line is the acceleration of the hanging weight. Record this acceleration.
8. Move masses so that the heavy mass m_1 is 5 g heavier than before and the light mass m_2 is 5 g lighter than before. That way the total mass $m_1 + m_2$ stays constant.
9. Repeat steps 3-8 for 11 different mass increments.

m_1 (g)	m_2 (g)	a (m/s^2)	m_1 (g)	m_2 (g)	a (m/s^2)

Data Processing

Rail cart

1. Find the formula for the expected acceleration of the ideal frictionless cart. Record it here.

2. Find the formula for the expected tension in the string of the ideal frictionless cart. Record it here.

3. Make a spreadsheet containing your data. (Copy last week's spreadsheet and delete everything but the rail cart data, or copy and paste last week's rail cart data into a new spreadsheet.) Arrange the data so that each run (hanging mass) is in a separate row. For each hanging mass, calculate in a new column what the dynamic tension f_k in the string should theoretically be when the cart is being accelerated by the falling weight.
4. Calculate in another column the residuals (deviations) between the expected and measured dynamic tensions: $s_{fi} = f_i - f_{i\,\mathrm{calc}}$.
5. In yet another column, calculate the squares of the residuals s_{fi}^2.
6. In another column, calculate what the acceleration of the cart should theoretically be.
7. In another column, calculate the residuals of the accelerations, $s_{ai} = a_i - a_{i\,\mathrm{calc}}$.
8. In another column, calculate the squares of the residuals s_{ai}^2.
9. Calculate the rms deviations σ for the tensions and for the accelerations. The formula for rms deviation is

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N} s_i^2}$$

where N is the number of measurements (in this case, hanging masses). Notice that the rms deviation has the same units as the measurements.

10. Make plots of:
    - f_i and $f_{i\ \mathrm{calc}}$ vs. hanging mass (both f series together in the same graph)
    - s_f vs. hanging mass
    - a_i and $a_{i\ \mathrm{calc}}$ vs. hanging mass (both a series together in the same graph)
    - s_a vs. hanging mass

Atwood machine

1. Find the formula for the expected acceleration of the frictionless Atwood machine. Record it here.

2. Enter your data into a new sheet in the spreadsheet. Use a separate row for each value of the lighter mass.
3. In a new column, calculate the expected accelerations a of the weights.
4. In a new column, calculate the residuals in the accelerations (the differences between the measured and expected accelerations) $s_{ai} = a_i - a_{i\ \mathrm{calc}}$.
5. In a new column, calculate the squares of the residuals s_{ai}^2.
6. Calculate the rms deviation for the accelerations.
7. In a new column, calculate the difference between the hanging masses $m_2 - m_1$.
8. Make plots of:
    - a_i and $a_{i\ \mathrm{calc}}$ vs. light mass (both a series together in the same graph)
    - s_a vs. light mass
    - a_i vs. $m_2 - m_1$
9. Make a best-fit line to the a_i vs m_2-m_1 graph. Find the slope.

Lab Report

Present your findings in a brief, lucid report. It should contain the following parts.

Data and results

Share your spreadsheet, containing the well-labeled data, calculations, and plots, with me.

Discussion

Answer the following questions in complete sentences. Include your answers in your spreadsheet, share as another document, or upload as text to Canvas.

Rail cart

Do the calculated and measured tensions f_k match?

How large is the rms deviation for the tensions compared to the differences between the different measured tensions?

Is there a pattern to the residuals plot? If there is or isn't, what does that mean?

Do the calculated and measured accelerations match?

How large is the rms deviation for the accelerations compared to the differences between the different measured accelerations?

Is there a pattern to the residuals plot? If there is or isn't, what does that mean?

Atwood machine

Do the calculated and measured accelerations match?

How large is the rms deviation for the accelerations compared to the differences between the different measured accelerations?

Is there a pattern to the residuals plot? If there is or isn't, what does that mean?

Is the a_i vs m_2-m_1 plot linear or not? Should it be linear?