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, one 500-g hanging mass, one mass hanger with masses, Capstone data setup, pad for the floor
Rail cart: data from last week

Data Collection

One end of the string is loaded with a hanging 500-g mass. The other is loaded with a 50-g mass hanger that can carry a variety of slotted masses, up to a total of near 500 g. The heavy mass will fall, lifting the light mass until the heavy mass lands on the floor. It is best if a student catches the rising masses after the falling mass lands on the pad.

1. Place the pad under the pulley that will hang the 500-g mass.
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. Change the mass on the hanger.
9. Repeat steps 3-8 for at least five different lighter masses, spanning the range from just over 0 g to just under 500 g.

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, or copy and paste last week's 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 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: $s_{fi} = f_i - f_{i\,\text{calc}}$.
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 be.
7. In another column, calculate the residuals of the accelerations, $s_{ai} = a_i - a_{i\,\text{calc}}$.
8. In another column, calculate the squares of the residuals s_{ai}^2.
9. Calculate the standard deviations for the tensions and for the accelerations. The formula for standard deviation is

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

   where N is the number of measurements (in this case, hanging masses). Notice that the standard deviation has the same units as the measurements.
10. Make plots of:
    - f_i and $f_{i\,\text{calc}}$ vs. hanging mass (both f series together in the same graph)
    - s_f vs hanging mass
    - a_i and $a_{i\,\text{calc}}$ 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. Copy 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 standard deviation for the accelerations.
7. 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

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

Share this as another document or upload to Canvas.

Rail cart

Do the calculated and measured tensions match?

How large is the standard deviation for the tensions compared to the 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?

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Atwood machine

Do the calculated and measured accelerations match?

How large is the standard deviation for the accelerations compared to the measured accelerations?

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