LAB 5. ATWOOD MACHINE

Introduction

A classic experiment in physics is the Atwood machine: two masses on either side of a pulley connected by a light string. When released, the heavier mass accelerates downward while the lighter one accelerates upward at the same rate. The acceleration depends on the difference in the two masses as well as on the total mass.

In this lab, you will determine the relationship between these two factors which influence the acceleration of an Atwood's machine using a meter stick, a stopwatch, and a kinematic model to determine acceleration.

Objectives

- Understand Newton's Second Law for connected objects
- Determine the relationships between acceleration and the masses on an Atwood machine

Supplies

Meter stick, mass set with hangers, string, stop watch, double pulley with stand

Investigation

Part 1. Constant total mass

For this part of the experiment you will keep the total mass constant, but move weights from one side to the other. The difference in masses changes.

1. Set up the Atwood machine apparatus as shown in Figure 1. Be sure the heavier mass starts sufficiently high off the ground, and hits the floor before the lighter mass reaches the pulley.
2. Arrange a collection of masses totaling 200 g on m_2 and a 200 g mass on m_1. Move 5 g from m_2 to m_1. Measure the height of the heavier mass above the ground before you release it. Record the height and masses in the data table.
3. Release the mass and allow it to fall using the stopwatch or smart device to measure the time required to hit the ground. Record this time in the data table.
4. Use the appropriate one-dimensional kinematic equation to determine the acceleration from the height and drop time. Record your calculations in the calculation table.
5. Continue to move masses from m_2 to m_1 in 5-g increments, changing the difference between the masses, but keeping the total mass constant. Repeat the preceding steps for each mass combination. Repeat for at least five different combinations.

Part 2. Constant mass difference

For this part of the experiment you will keep the difference in mass between the two sides of the Atwood machine constant and increase the total mass.

1. Put 120 g on m_1 and 100 g on m_2.
2. Repeat the steps in Part 1, measure the drop time, and determine the acceleration.

3. Add mass in 20-g increments to both sides, keeping a constant difference of 20 grams. Record the resulting mass for each combination in the data table. Repeat the steps in Part 1 for each combination. Repeat the procedure until you try at least five different combinations.

Data Table 1. Constant total mass

Trial	m_1 (g)	m_2 (g)	Δh (m)	Δt (s)
1				
2				
3				
4				
5				

Data Table 2. Constant mass difference

Trial	m_1 (g)	m_2 (g)	Δh (m)	Δt (s)
1				
2				
3				
4				
5				

Data Processing

It may be worthwhile to enter your data into a spreadsheet and code the spreadsheet to carry out the calculations.

1. For each trial, calculate the difference Δm between m_1 and m_2, $\Delta m = m_1 - m_2$. Enter the result in the column labeled "Δm."
2. For each trial, calculate the total mass. Enter the result in the column labeled "M."
3. Compute an additional column for $1/M$ in the Part 2 (Constant mass difference) table.
4. Plot a graph of acceleration vs. Δm, using the Part 1 data.
5. Plot a graph of acceleration vs. total mass M, using the Part 2 data.
6. Plot a graph of acceleration vs. $1/M$, using the Part 2 data.
7. For all trials, calculate the acceleration predicted by your model. Enter the result in the column labeled "model a." From this acceleration, calculate the predicted time for the weight to reach the ground. Enter this result in the column labeled "model Δt."

Calculation Table 1. Constant total mass

Trial	**Δm (g)**	**M (g)**	**a (m/s^2)**	**model a**	**model Δt**
1					
2					
3					
4					
5					

Calculation Table 2. Constant mass difference

Trial	**Δm (g)**	**M (g)**	**$1/M$ (g^{-1})**	**a (m/s^2)**	**model a**	**model Δt**
1						
2						
3						
4						
5						

Questions

1. Based on your analysis of the Part 1 graph, what is the relationship between the mass difference and the acceleration of an Atwood machine?

2. Based on your analysis of the Part 2 graphs, what is the relationship between total mass and the acceleration of an Atwood machine?

3. What do the combined results of all the graphs suggest about the full equation for acceleration? Do these graphs agree with your derivation in the Pre-lab?

4. For both parts 1 and 2, compare the measured drop times to the drop times calculated by your model. Are the experimental drop times low or high?

5. Why might the measured times differ from the predictions of the model? Consider all sources of systematic and random error. Do not blame "human error" without explaining specifically what that may mean.