

Atwood's Machine

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

In this lab, you will determine the relationship between the two factors that influence the acceleration of an Atwood's machine using a Photogate to record the machine's motion.

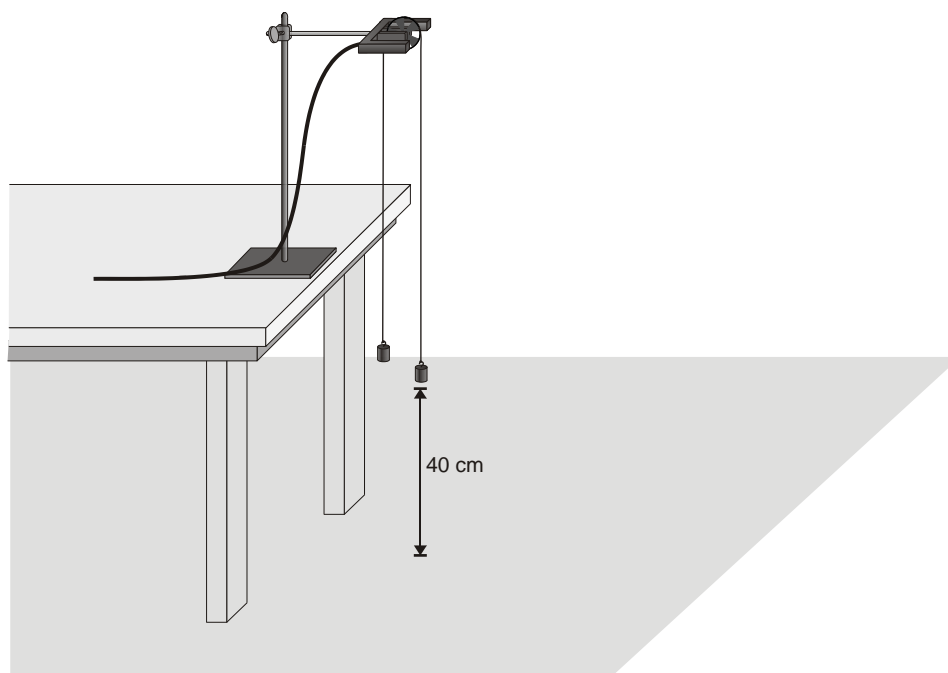


Figure 1

PRELIMINARY QUESTIONS (DO THESE BEFORE LAB)

1. If two objects of equal mass are suspended from either end of a string passing over a light pulley (an Atwood's machine), what kind of motion do you expect to occur? Why?
2. For an Atwood's machine, how would you expect the acceleration to change if you:
 - Move mass from one side to the other, keeping the total mass constant?
 - Gradually increase the mass of both sides, keeping the difference in mass constant?
3. Why do the two masses have the same acceleration?
4. Draw a free-body diagram of the left side mass. Draw another free-body diagram of the right side mass. Include all forces acting on each mass.

I.) PURPOSE

- Use a Photogate to study the acceleration of an Atwood's machine.
- Determine the relationships between the masses on an Atwood's machine and the acceleration.

II.) MATERIALS

LabQuest	mass set
LabQuest App	string
Vernier Photogate with Ultra Pulley Attachment	(optional) Logger <i>Pro</i> or graph paper

III.) PROCEDURE

Part I Constant Total Mass

For this part of the experiment you will keep the total mass used constant, but move weights from one side to the other.

1. Set up the Atwood's machine apparatus as shown in Figure 1. Be sure that the masses can move at least 40 cm before the heavier mass strikes the floor.
2. Connect the Photogate to DIG 1 of LabQuest and choose New from the File menu
3. Set up LabQuest for a pulley with a string that runs in a groove.
 - a. On the Meter screen, tap Mode.
 - b. Select Pulley (10 spoke) in groove.
 - c. Select OK.
4. Arrange a collection of masses on your Atwood's machine for m_1 and for m_2 .
5. To measure the acceleration of this system, pull the smaller mass down about 40 cm. Steady the masses so they are not swinging. Start data collection. After a moment, release the smaller mass, catching the falling mass before it strikes the floor or the other mass strikes the pulley.
6. Display only the velocity vs. time graph by choosing Show Graph ► Graph 2 from the Graph menu. Examine the graph. The slope represents the acceleration of the masses.
7. Fit a straight line to the velocity vs. time graph.
 - a. Choose Curve Fit from the Analyze menu.
 - b. Select Linear as the Fit Equation.
 - c. Record the slope of the linear curve fit (acceleration) in the data table.
 - d. Select OK.
8. Remove 10 g from m_2 and add it to m_1 . Note that the total mass remains the same.
9. Repeat Steps 5–7 to determine the acceleration of this new mass combination, recording the values in the data table.

10. Continue to move masses from m_2 to m_1 in 10 g increments, changing the difference between the masses, but keeping the total constant. Repeat Steps 5–7 for each mass combination. Record the data in the data table.

Part II Constant Mass Difference

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

11. Start with a 20 g difference between m_1 and m_2 .
12. As you did before, collect data and determine the acceleration.
13. 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. Collect motion data and determine the acceleration for at least five different mass combinations.

IV.) DATA TABLE

Part I: Constant Total Mass					
Trial	m_1 (g)	m_2 (g)	Acceleration (m/s ²)	Δm (g)	m_T (g)
1					
2					
3					
4					
5					

Part II: Constant Mass Difference					
Trial	m_1 (g)	m_2 (g)	Acceleration (m/s ²)	Δm (g)	m_T (g)
1					
2					
3					
4					
5					

V.) CALCULATIONS

1. For each trial, calculate the difference between m_1 and m_2 in grams. Enter the result in the column labeled Δm .
2. For each trial, calculate the total mass in grams. Enter the result in the column labeled m_T .
3. Using graph paper, plot a graph of acceleration vs. Δm , using the Part I data. Based on your analysis of the graph, what is the relationship between the mass difference and the acceleration of an Atwood's machine?
4. Similarly construct a graph of acceleration vs. total mass, using the Part II data. Based on your analysis of the graph, what is the relationship between total mass and the acceleration of an Atwood's machine?
5. Develop a single expression for the acceleration of an Atwood's machine, combining the results of the previous two steps in the analysis.

VI.) QUESTIONS

1. Draw a free body diagram of m_1 and another free body diagram of m_2 . Using these diagrams, apply Newton's second law to each mass. Assume that the tension is the same on each mass and that they have the same acceleration. From these two equations, find an expression for the acceleration of m_1 in terms of m_1 , m_2 , and g . Compare the expression to your result in Step 5 of Analysis.
2. For each of the experimental runs you made, calculate the expected acceleration using the expression you found with Newton's second law of motion and the specific masses used. Compare these figures with your experimental results. Are the experimental acceleration values low or high? Why?