  Graphical Analysis 10

Atwood’s Machine

A classic 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 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 the total mass.

In this experiment, 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.

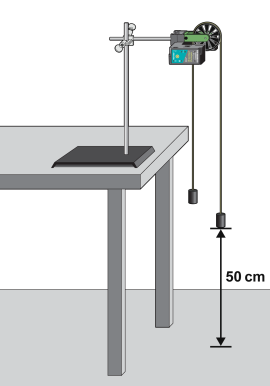


Figure 1

objectives

* 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.

Materials

Chromebook, computer, or mobile device

Graphical Analysis 4 app

Go Direct Photogate with Ultra Pulley Attachment

ring stand

right-angle clamp

mass set

string, 1.2 m long

graph paper (optional)

Preliminary questions

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

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. The difference in masses changes.

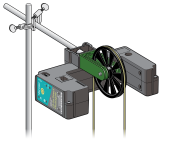


Figure 2

1. Set up the Atwood’s machine apparatus as shown in Figures 1 and 2. Note: The masses must be able to move at least 40 cm before the heavier mass strikes the floor.
2. Launch Graphical Analysis. Connect the Photogate with Ultra Pulley to your computer, Chromebook, or mobile device. Click or tap Sensor Channels, and select Gate 2 - Gate State only.
3. Set up Graphical Analysis for a pulley with a string that runs in a groove.
   1. Click or tap Mode. Graphical Analysis is set to Photogate Timing, Linear Motion mode.
   2. Change the Object to Ultra Pulley - in groove.
   3. Click or tap Done.
4. Arrange a collection of masses totaling 100 g on m2 and a 100 g mass on m1. What is the acceleration of this combination? Record your values for mass and acceleration in the data table.
5. Move 5 g from m2 to m1. Record the new masses in the data table.
6. To measure the acceleration of this system, start with the masses even with each other. Steady the masses so they are not swinging. Click or tap Collect to 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. Click or tap Stop to stop data collection.
7. Click or tap View, , and choose 1 Graph. If necessary, change the y-axis to display a graph of velocity vs. time. Examine the graph. The slope represents the acceleration of the masses.
8. Fit a straight line to the velocity vs. time graph.
   1. Click or tap Graph Tools, , and choose Apply Curve Fit.
   2. Select Linear as the curve fit.
   3. Record the slope of the linear curve fit (acceleration) in the data table and then dismiss the Linear curve fit box.
9. Continue to move masses from m2 to m1 in 5 g increments, changing the difference between the masses, but keeping the total constant. Repeat Steps 6–8 for each mass combination. Continue until you collect data for at least five different mass combinations.

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.

1. Use 50 g for m1 and 60 g for m2.
2. Repeat Steps 6–8 to collect data and determine the acceleration.
3. Add mass in 10 g increments to both sides, keeping a constant difference of 10 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.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Data Table  Part I  Constant Total Mass   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Trial | m1 (kg) | m2 (kg) | Acceleration (m/s2) | mdiff, m1–m2 (kg) | mT (kg) | | 1 |  |  |  |  |  | | 2 |  |  |  |  |  | | 3 |  |  |  |  |  | | 4 |  |  |  |  |  | | 5 |  |  |  |  |  | |

Part II  Constant Mass Difference

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Trial | m1 (kg) | m2 (kg) | Acceleration (m/s2) | mdiff, m1–m2 (kg) | mT (kg) |
| 1 |  |  |  |  |  |
| 2 |  |  |  |  |  |
| 3 |  |  |  |  |  |
| 4 |  |  |  |  |  |
| 5 |  |  |  |  |  |

Analysis

1. For each trial, calculate the difference between m1 and m2. Enter the result in the column labeled mdiff.
2. For each trial, calculate the total mass in grams. Enter the result in the column labeled mT.
3. Plot a graph of acceleration vs. mdiff, 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, plot a graph of acceleration vs. mT, using the Part II data. Based on your analysis, 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.

EXTENSIONS

1. Draw a free body diagram of m1 and another free body diagram of m2. 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 m1 in terms of m1, m2, 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?
3. An unknown mass can be placed on one side of the Atwood’s machine. Using lab measurements and any necessary calculations, the mass of the unknown can be determined. Try it.
4. How does the force exerted upward by the pulley change as the system begins accelerating? Why? Set up an experiment to determine how this force changes.
5. How does the tension in the string change as the masses start to move? Or does it?