# Atwood’s Machine

Guided Inquiry

Driving Question | Objective

How is the acceleration of the two masses of an Atwood’s machine affected by their difference in mass and by their total mass? Experimentally determine the mathematical relationship between the acceleration of an Atwood’s machine, the difference between its two masses, and the sum of those two masses.

Design and Conduct Your Experiment

It is your group’s responsibility to design and conduct an experiment whose data will support your answer to the driving question above. Use the answers to the guiding questions below to help guide your experiment design. After you have answered the guiding questions, write an outline of the equipment setup and procedure you will use to collect data, identifying the steps in sequence and the points at which each piece of equipment will be used.

Suggested Materials and Equipment

Although you have the freedom to design your procedure using any reasonable equipment at your disposal, the following equipment is recommended for your experimental setup.

|  |  |
| --- | --- |
| * Data collection system | * Table clamp or large base |
| * PASCO Wireless Smart Gate photogate1 | * Support rod, 60-cm or taller |
| * PASCO Super Pulley with Mounting Rod | * Multi-clamp |
| * Mass and Hanger Set | * Thread, about 1 m |
|  | * Scissors |

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| 1[www.pasco.com/ap38](http://www.pasco.com/ap38) |
|  |
| PASCO Wireless  Smart Gate |

Guiding Questions

* 1. If the objective of this lab is to experimentally determine how the difference in mass and the total mass of the two Atwood’s machine masses affect the system’s acceleration, what should the dependent and independent variables be in your experiment?

* 2. What equipment do you have available and how will you set it up to measure each variable?

* 3. How will you change each independent variable while collecting data? Should you change more than one variable at a time? Describe the steps you will take to change each variable.

* 4. An ideal Atwood’s machine is frictionless and its string and pulley are massless. How will you design your experiment to approximate these ideals as closely as you reasonably can?

Experimental Design

Your goal is to experimentally determine the mathematical relationship between acceleration, mass difference, and total mass of the two masses of an Atwood’s machine. Use the responses to the Guiding Questions to help finalize your procedure and your equipment configuration.

Once you are convinced that your procedure will accomplish the experiment's objectives, record your experimental setup and procedure in the following sections.

Setup

Draw and/or describe your experimental setup such that a third party could recreate the same setup in an attempt to reproduce your experiment.

Procedure

Outline the procedure you will use in your experiment, listing all of the steps below. Your outline should be written such that a third party could follow the same procedure in an attempt to reproduce your experiment.

Collect Data

Perform your experiment and record all relevant data. Present your data below (or in an attached document) in a form that best suits the experiment format, such that a third party can understand your experimental results in an attempt to reproduce them.

Analysis Questions

* 1. For each part of your experiment, list each variable and indicate whether it was held constant, increased, or decreased.

* 2. How did changing the difference in mass between the two sides affect the acceleration of the Atwood’s machine?

* 3. Based on your data, express the relationship between the acceleration  and mass difference   
  m2 – m1 by completing this proportionality statement:

|  |  |  |
| --- | --- | --- |
|  |  | (total mass held constant) |

* 4. How did changing the sum of the two hanging masses affect the acceleration of the Atwood’s machine?

* 5. Based on your data, express the relationship between the acceleration  and total mass m2 + m1 by completing this proportionality statement:

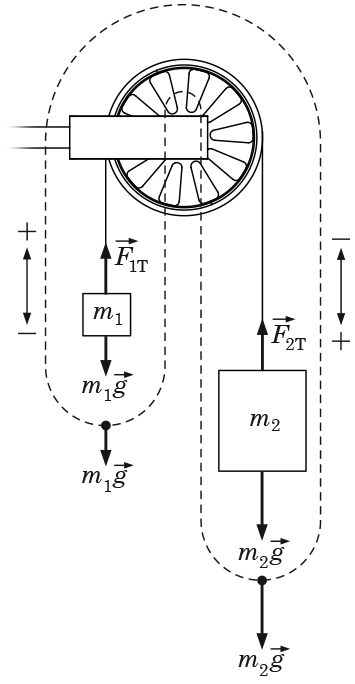
|  |  |  |
| --- | --- | --- |
|  |  | (mass difference held constant) |

* 6. Combine the two relationships above into a single proportionality expressing the relationship between the Atwood’s machine’s acceleration  the mass difference m2 – m1 and the total mass   
  m2 + m1:

|  |  |
| --- | --- |
|  |  |

* 7. Convert the proportionality statement above into an equation by introducing a proportionality constant k:

|  |  |
| --- | --- |
|  |  |

* 8. Consider this free-body diagram of an Atwood’s machine. Assume that the masses of the string and pulley are negligible. The analysis can be simplified if the system is defined to consist of the two masses linked together, as indicated by the dashed line. This allows you to disregard the string tension as an internal force and consider only the two forces m1g and m2g acting on the system. You can also consider the system to be moving in one dimension, with positive defined in the direction of m1 ascending and m2 descending, as indicated.

Apply Newton’s Second Law,  , to derive an expression for the acceleration  of the system in terms of the masses m1 and m2.

* 9. How does the expression for acceleration that you determined from your data analysis compare to the equation derived above from Newton’s Second Law? Justify your answer.

Synthesis Questions

* 1. One way to check whether a derived relationship is reasonable is to consider whether it behaves as expected in extreme or limiting cases. Determine whether the relationship you derived between the acceleration a of an Atwood’s machine and its two hanging masses m2 and m1 reduces to a reasonable form when the two masses are equal. Explain your reasoning.

* 2. Similarly, determine whether the relationship you derived between the acceleration a of an Atwood’s machine and its two hanging masses m2 and m1 reduces to a reasonable form when the mass m2 is much greater than m1. Explain your reasoning.

* 3. A planetary rover carries an Atwood’s machine with 100 g one side and 110 g on the other. If the system’s acceleration is measured to be 0.176 m/s2 on a certain planet, what is the acceleration due to gravity on that planet? Which planet in the solar system is it?

* 4. What ratio of masses m2/m1 would produce an Atwood’s machine whose acceleration is half that of an object in free fall?
* 5. Elevators cars have counterweights to reduce the amount of work motors need to do to lift the car. You might idealize an elevator system without its motor as an Atwood’s machine. If a particular elevator’s counterweight mass is 1,000 kg and its elevator car and passengers have a combined mass of 1,200 kg, what acceleration would the passengers experience if the motors and safety braking mechanisms failed? If the elevator car accelerated from rest at a height of 12 m above the ground floor, how long would it take for the car to reach the ground floor? What would be its speed on impact?