Lab4 - Atwood's Machine

Purpose:
To measure the acceleration of gravity using an Atwood's machine.

Description:
In order to slow down a falling object, we need to apply a force to the object in the upward direction. This can be done using an Atwood's machine: two different masses connected by a string over a pulley. For \( m_2 > m_1 \), the acceleration is given by:

\[
a = g \frac{(m_2 - m_1)}{(m_2 + m_1)}
\]

By picking the value of the masses, we can tune the acceleration to a manageable value (< 9.81 m/s\(^2\)) so that the elapsed times can be measured accurately by hand. Using the elapsed time, we can calculate \( a \) and in turn, \( g \).

Before you come to lab show that:
For \( m_2 > m_1 \), the acceleration is given by:

\[
a = g \frac{(m_2 - m_1)}{(m_2 + m_1)}
\]

Draw a free body diagram of the Atwood machine setup and use Newton’s 2\(^{nd}\) law to obtain the relation between \( a \) and \( g \) above. You can assume a massless and frictionless pulley.
**Equipment:**
Computer, meter stick and stop watch, masses, and 50 g holder table clamp, long bar 3 ft, cross clamp, Atwood’s machine pulley, string.

**Procedure:**

1. You can use the table to record your average time and calculated value for g:
   *The masses are a suggestion – use masses so that the drop time is large enough that the issue of your reaction time is minimized (see below testing reaction time)*

<table>
<thead>
<tr>
<th>Trial</th>
<th>m2 (g)</th>
<th>m1(g)</th>
<th>t(s)</th>
<th>a: m/s² (experimental)</th>
<th>a: m/s² (theoretical)</th>
<th>g (experimental)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>205</td>
<td>195</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2</td>
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<td>165</td>
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<tr>
<td>5</td>
<td>250</td>
<td>150</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**don’t really need**

Mean g:

Include your table in your report.

2. Set up your Atwood’s machine: Mount the pulley is as high as possible. Tie one end of the string to mass 1 and tie the other end to mass 2. Hang the masses over the pulley then adjust the pulley height so that the bottom of the upper mass is 1.2-1.3 m above the floor when the lower mass is on the floor.

3. Experiment: Pull the lighter side to the floor. Measure the time required for the heavier side to hit the floor. **Drop the mass three times**, and then **repeat for five mass pairs**. Each drop should have its own row in the spreadsheet.

The displacement d and average elapsed time t are related by the following kinematical equation \(d = \frac{1}{2} a t^2\). Thus you can find \(a_{\text{experimental}}\) from this equation.

It is good experimental procedure to check the quality of your data as you go. Have Excel calculate a value for g for every drop. If there are large deviations from the expected value of g, discuss your experimental procedures with your lab partner.
Analysis:
Make a plot of your data with acceleration on the y axis and \((m_2 - m_1)/(m_1 + m_2)\) on the x axis. Fit a line to these data. The slope should be the acceleration due to gravity, and the intercept should be close to zero. You can also choose to set it to zero when you fit the line.
Include the plot in your report.

The slope of the line is one way to determine a value for \(g\), and in most careful experiments, it is the preferred method. Another way of determining \(g\) is to simply take the mean of the values of \(g\) you have calculated at each trial. Does the difference between the two values fall within the expected error bars? If the value from the slope is much different that the "point values", this usually is a clue to a source of error. Discussion of this is one of the things that should be found in your conclusion.

Use what you learned in lab #2 to find out how accurate your results are.

Conclusion:
Compare your experiment value of \(g\) to the expected value. What sources of errors may have affected your result? Also discuss the accuracy of your results and comment on any points that deviate from the expected value.

*Testing reaction time*
Before building your Atwood’s machine, test your reaction time. Have one lab partner hold a ruler and position the other to catch it. The second lab partner should grab the ruler as quickly as possible after the first drops it. Measure the distance the ruler dropped and use the following kinematical equation:

\[ d = V_i t + \frac{1}{2} a t^2 \]

Since \(V_i = 0\) and \(a = g\), this gives

\[ t = \sqrt{\frac{2d}{g}} \]

Repeat this measurement several times to get an idea of your average reaction time. Note that you can use the same general thinking to predict how long each trial of your Atwood's Machine experiment will take. In this case, \(d\) is the distance that the mass drops, and \(a\) will equal \((m_2 - m_1)/(m_1 + m_2)g\). Pick your masses such that this time is large enough that the issue of your reaction time is minimized.