

SAMPLE LABORATORY REPORT

ATWOOD MACHINE

Procedure

The purpose of this experiment was to verify the predictions of Newton's Law $F = ma$ for an Atwood machine, a simple machine constructed by hanging two different masses m_1 and m_2 from a string passing over pulleys and observing their acceleration. Newton's Law predicts that the acceleration should be proportional to the difference between the masses and proportional to their sum,

$$a = \frac{m_1 - m_2}{m_1 + m_2} g, \quad (1)$$

where $g = 9.8 \text{ m/s}^2$ is the acceleration due to gravity.

The Atwood machine apparatus consisted of a pair of light-weight plastic pulleys, approximately 4 cm in diameter, which were supported by a rod. A hooked mass hanger, with a 50 g mass, was placed on each end of a string hanging over the pulleys, and masses were stacked on each hanger. The acceleration was measured for various combinations of the two masses.

For the first set of trials, we selected a set of slotted metal 5 and 10 g weights with a total mass of 200 g, and placed 50 g on each side, so that $m_1 = m_2 = 100 \text{ g}$, including the hangers. Then, the masses were moved from side 2 to side 1 in 5 g increments. The lighter mass was lowered into a catch box containing a foam pad, and the drop distance h was measured from the pad to the bottom of the hanger for the heavier mass, using a meter stick marked in 1 mm increments. The drop height measured to be 130.0 cm, to an accuracy of about $\pm 1 \text{ mm}$. This was the same for all trials. When the heavier mass was released, a stop watch was used to measure the time until it reached the catch box. Three

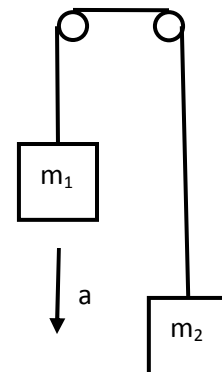


FIG. 1: Atwood Machine

times were measured for each drop, and the results averaged. The results for five drops with different mass differences are shown in table 1 for the first set of drops. Table 2 shows another set of drops with a total mass of 400 g, made of individual 5 or 10 g masses. While the individual measurements are not shown in the table, the average difference between the measurements suggests a timing error of about ± 0.1 s, which seems reasonable given the possible variation in reaction times while starting and stopping the watch. To minimize reaction time errors, the person who dropped the mass counted down, so that the start time could be predicted more readily by the stop-watch operator. It seems reasonable that this procedure could limit the reaction time error to be within the ± 0.1 s random error seen among the various time readings taken.

Analysis

The results of the timing measurements are shown in Tables 1 and 2 for the trials with total masses of 200 g and 400 g, respectively. The measured acceleration is obtained from the drop time and measured height using the relation

$$a = \frac{2h}{t^2}. \quad (2)$$

The predicted accelerations calculated using eqn. (1) are shown as well, for comparison. The measured and calculated values of acceleration are plotted in Figure 2 as a function of the mass difference $\Delta m = m_1 - m_2$.

TABLE 1: $m_1 + m_2 = 200$ g

m_1 (g)	m_2 (g)	$m_1 - m_2$ (g)	t (s)	a : eq. (2) (m/s^2)	a : eq. (1) (m/s^2)
105	95	10	2.40	0.450	0.490
110	90	20	1.61	1.00	0.980
115	85	30	1.37	1.39	1.47
120	80	40	1.12	2.07	1.96
125	75	50	0.98	2.7	2.45

TABLE 2: $m_1 + m_2 = 400$ g.

m_1 (g)	m_2 (g)	$m_1 - m_2$ (g)	t (s)	a : eq. (2) (m/s^2)	a : eq. (1) (m/s^2)
205	195	10	3.41	0.224	0.245
220	180	40	1.77	0.827	0.980
230	170	60	1.30	1.55	1.47
235	165	70	1.20	1.82	1.72
250	150	100	0.99	2.64	2.45

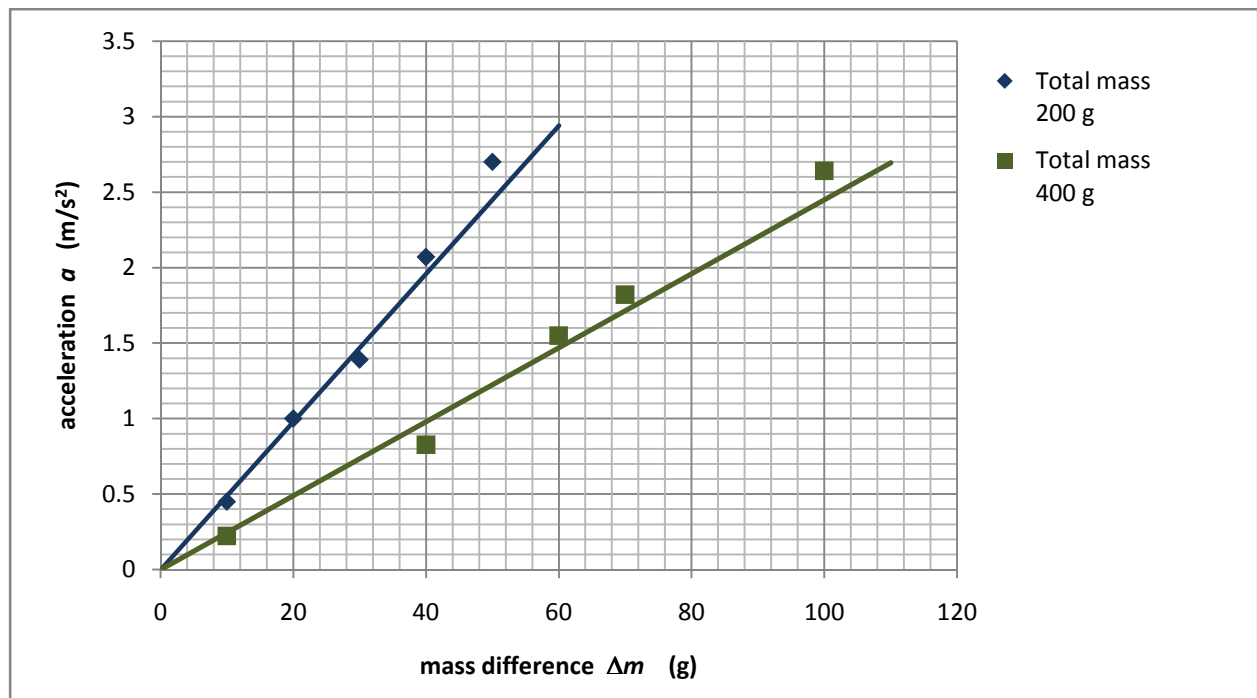


FIG. 2: Plot of the acceleration as a function of the mass difference Δm for the two trials with total mass 200 g and 400 g. The solid lines show the calculated results.

Discussion

In this experiment, we measured the acceleration of the masses in an Atwood machine and compared the results to the prediction of Newton's Law, which is given by eqn. (1). That equation implies that the acceleration should increase linearly with the mass difference Δm . The expected line is plotted together with the corresponding data points. We find overall agreement with this prediction. However, Fig. 1 shows some minor departures from the prediction, including, most notably, a trend for the data points with large Δm to lie above the expected line.

One possible source of error in this experiment is friction, which is not included in the analysis leading to eqn. (1). However, friction cannot explain accelerations which are greater than expected, since friction would tend to reduce the acceleration. A different explanation is needed for the trend of the points with large accelerations to lie above the expected line. It is useful to remember that the points with large accelerations have short time measurements. The short time measurements are more difficult, and could be subject to greater error. Although our timing consistency was apparently within ± 0.1 s for all of the data, this is a bigger *fraction* of the time for large Δm , leading to a potentially greater error in the calculated acceleration. Also, this timing error could be systematic, not just random: a reaction time delay

would shorten all of the times, and this would have the greatest effect on the times that were short to begin with. Shortened times correspond to larger accelerations, according to eqn. (2), so a reaction time delay would be expected to give larger accelerations for larger mass differences. This is consistent with what is seen in the data.

For example, considering the last entry in Table 1, the measured acceleration was about 10% high. The predicted acceleration would have been obtained if $t = 1.03$ s had been measured, which is 0.05 s longer than the measurement shown. A 0.05 s reaction time delay is reasonable, and is within our expected error of ± 0.1 s, so we can conclude that even the data at the high end of the graph agree with the predicted results, within our experimental accuracy.

One other data point appears to be out of line: the $\Delta m = 40$ g measurement in the 400 g series. In that case, the expected result would have been found from eqn. (2) if the time had been $t = 1.63$ s instead of 1.77 s. This is a difference of 0.14 s, which is slightly higher than the typical error, but within the bounds of reasonable expectations for a measurement of this type. All of the remaining points show better agreement, so it may be concluded that the experimental measurements confirm the predictions of Newton's Law for the Atwood machine to within the bounds of the experimental accuracy.