

Laboratory 7: Newton's Second Law: Atwood's Machine – Prelab

1 Atwood's machine

Atwood's machine consists of two masses suspended over a pulley. An example is illustrated in Fig. 1.

- a) Draw a free body diagram for each block. Describe whether the vertical component of the acceleration for each block is positive or negative.

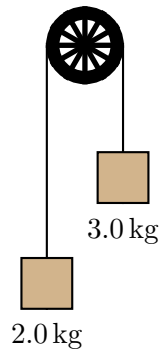


Figure 1: Atwood's machine.

- b) Starting with Newton's second law for each block, determine the magnitude of the acceleration of the blocks.

Laboratory 7: Newton's Second Law: Atwood's Machine – Activity

Atwood's machine consists of two blocks connected by a string suspended over a pulley as illustrated in Fig. 2. Typically the two blocks are released from rest. Newton's laws can be used to predict their subsequent acceleration, which can also be determined by measuring the speeds of the blocks as time passes. The aim of this experiment is to verify the accelerations as predicted by Newton's second law.

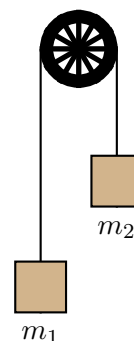


Figure 2: Atwood's machine. Block 1 is on the left, block 2 is on the right.

1 Theory and experimental design

- Suppose that the string cannot stretch. How is the velocity of block 1 at one instant related to that of block 2 at the same instant? How is the acceleration of block 1 related to that of block 2?
- Assume that $m_2 > m_1$ and consider block 1 in Fig. 2. Is the y -component of its acceleration positive, negative or zero? Is the y -component of the acceleration of block 2 positive, negative or zero?

Denote the *magnitude of the acceleration* of each block by a .

- Express the y -component of each block's acceleration in terms of a .
- Draw a free body diagram for *each block*.
- Apply Newton's second law separately to *each block*. This should give two equations with two unknowns: a and the tension in the string. Combine these to determine an expression for the magnitude of the acceleration, i.e.

$$a = \text{formula where the only allowed symbols are } m_1, m_2 \text{ and } g.$$

- What does your expression predict for the acceleration when the blocks have the same mass? Does your prediction appear to be correct? If it predicts this correctly, then have the instructor check your expression for the acceleration.
- The sensor records the speed of block 1 versus time. How can the acceleration of the this block be determined from this data?

2 Experiment: acceleration

The pulley is equipped with a sensor which determines the *speed* with which the edge of the pulley is moving; this equals the speed with which either of the blocks move. The PASCO interface can record this speed as time passes and CapStone can graph this data. The acceleration of either block can be inferred from this graph.

- a) Set up CapStone and configure it to read speed via the photogate (see page 6).
- b) Set up the mass hangers and choose values of m_1 and m_2 (it is best to arrange these so that there is not a huge discrepancy in mass on either side). Predict the acceleration of the mass on the left. Denote this a_{theory} .
- c) Arrange mass with the values of m_1 and m_2 used above. Release them from rest and determine the acceleration of that on the left. Denote this a_{exp} .
- d) Determine the percentage difference:

$$\frac{a_{\text{theory}} - a_{\text{exp}}}{a_{\text{theory}}} \times 100.$$

- e) Repeat the previous steps for two more different arrangements of m_1 and m_2 .
- f) What may have caused the discrepancies? One thing to check is the acceleration when $m_1 = m_2$. What acceleration should result? For two different values of $m_1 = m_2$, set up the masses and record the speed of that on the left vs time after giving the mass on the right a gentle downward pull. Measure and record the acceleration. Do the experimental results match your predictions? If not, how could they explain the discrepancies between measured and calculated accelerations?

We will now consider whether the direction of motion affects the acceleration. Suppose that $m_2 > m_1$ and that the blocks are initially held at rest. Then block 1 is given a brief sharp tug down. It moves down and then reverses direction.

- g) Predict how the magnitude of the acceleration when moving down compares to that when moving up (same, larger smaller, etc, ...)?
- h) Set up the masses as indicated. Run CapStone, give the lighter mass a brief tug and release it. Graph velocity versus time.
- i) You should observe a period during which the mass on the left moves down with decreasing speed followed by a period during which it moves up with increasing speed. Identify these on the CapStone plot and determine the acceleration for each period. Note that the **smart pulley** cannot distinguish between various directions of motion. This means that it will lose the sign of the velocity while the object moves down. So it will get the incorrect sign for the acceleration while the object moves down. After you have done this correction, how does the acceleration when moving down compare to that when moving up?

3 Tension in the string

It is possible to infer the tension in the string from the motion of the masses.

- a) Determine an expression for the tension in the string (on the left) in terms of the acceleration of the masses, i.e.

$$T = \text{formula where the only allowed symbols are } m_1, a \text{ and } g.$$

Have the instructor check your expression.

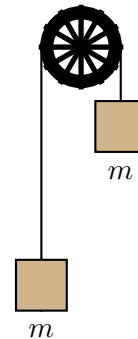
- b) Again consider the situation where $m_2 > m_1$ and block 1 is given an initial downward tug. Predict for the motion after the tug:
- How the tension in the string compares (larger, smaller, same) to the gravitational force on block 1 while it is moving down.
 - How the tension in the string compares (larger, smaller, same) to the gravitational force on block 1 while it is moving up.
 - How the tension in the string compares (larger, smaller, same) while block 1 is moving up to the tension in the string while block 1 is moving down.
- c) In part 2 (h) you recorded data for a run of this experiment. Use the acceleration data and the formula from part 3 (a) to determine the tension in the string throughout the motion. Does this depend on the direction of motion of block 1? How does it compare to the gravitational force on block 1?

4 Conclusion

- Does Newton's second law predict the accelerations correctly?
- What may have caused any discrepancies between measured and predicted accelerations?

5 Exercises

- Two identical masses are held in the illustrated arrangement. The masses are then released. Predict the subsequent motions of each mass (e.g. up, down, speeding up, slowing down, etc., ...). Explain your answer.
- Two identical masses are held at rest in the illustrated arrangement. A hand briefly pulls the mass on the right down. Predict the subsequent motion of each mass (e.g. up, down, speeding up, slowing down, etc., ...) before either mass hits the floor or pulley and after the hand leaves the mass. Explain your answer.



Setting up the photogate timer

To set up the photogate and super pulley to measure the linear velocity of the edge of the pulley, first connect Photogate in the interface icon. This will produce a Timer icon in the Tools palette. Click on the Timer icon and do as follows:

- ① Select Pre-configured and click next.
- ② Select Photogate Ch. 1 and click next.
- ③ Select Photogate with pulley and click next.
- ④ Check the Linear Speed box and click next.
- ⑤ Use the default parameters and click next.
- ⑥ Provide a name and and click next.
- ⑦ Click finish.