

# Physics 103 – Newton’s 2<sup>nd</sup> Law

## On Atwood’s Machine with Computer Based Data Collection

### Materials

Photogate with pulley, mass set, ~1.2 meter long string, LabPro analog to digital converter and a computer. In addition, you need the following cords: power cord for LabPro, cord to connect photogate to LabPro, cord to connect LabPro to computer.

### Introduction

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 lab, 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.

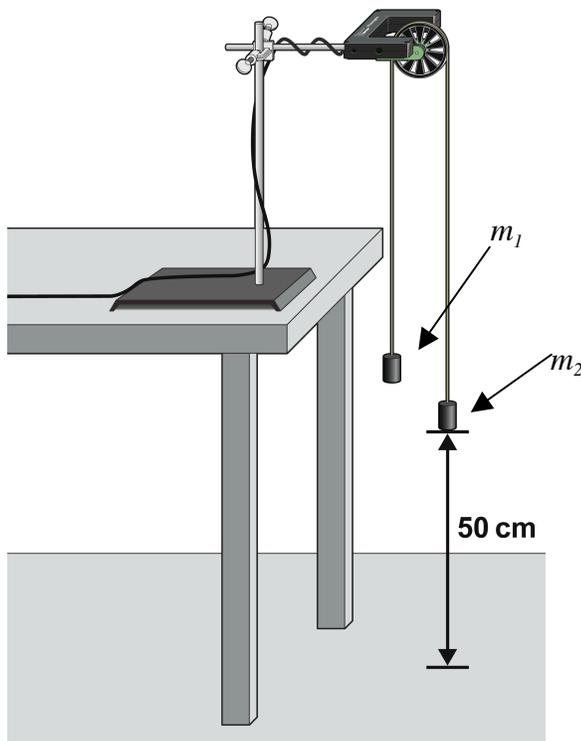


Figure 1

## 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.

## PRELIMINARY QUESTIONS

1. Do the two masses on the Atwood's machine have the same acceleration? Why or why not?
2. Suppose that you start with 300 grams on one side of the Atwood machine and 302 grams on the other. If you take a 2 gram mass from the 300 gram side and move it to the other side, what is the mass difference between the two sides now?
3. Suppose that you have a mass of  $m_1$  on one side of the Atwood machine and a mass of  $m_2$  on the other side. How much mass is accelerated as the objects fall? **a)** Only the smaller mass, **b)** only the larger mass, **c)** the difference in mass ( $m_2 - m_1$ ), or **d)** the total mass ( $m_1 + m_2$ )?
4. Is the acceleration of the hanging mass equal to the acceleration due to gravity? Why or why not?
5. 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?

## PROCEDURE

For this experiment you will **keep the total mass used constant, but move weights from one side to the other.** The difference in masses changes.

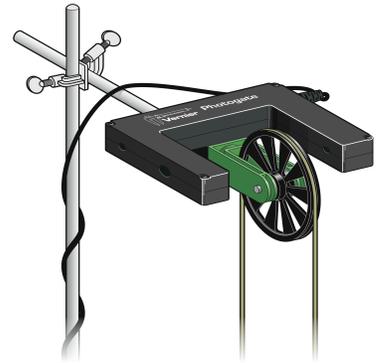


Figure 2

1. Check your set-up. Your equipment should be set up as shown in Figures 1 and 2. The masses must be able to move at least 40 cm before striking the ground. The photogate with pulley should be plugged into DIG1 on the LabPro which should be plugged into the electrical outlet and also connected to the computer.
2. **Open the file atwood in the PHY230 folder** on the desktop. The collect button (arrow) at the top of the page should be green. If it is not, check that your LabPro is plugged into an outlet and connected to the computer. If the collect button is still not green, unplug the LabPro and plug it back in. If the collect button is still not green, let your instructor know.
3. Arrange a collection of masses **totaling 300g on one side** of the Atwood's machine. (See Figure 1 above.) **We will call the LIGHTER SIDE  $m_1$ .** Arrange a collection of masses **totaling a 302g on the other side** of the Atwood's machine. **We will call the HEAVIER SIDE  $m_2$ .**
4. **Move 2 g from  $m_1$  to  $m_2$ .** Record the new masses in the data table.
5. Check that the pulley wheel is completely vertical (not tipped sideways at all) and that the string connecting the two masses is still over the wheel.
6. To measure the acceleration of this system, start with the masses hanging even with one another. Steady the masses so they are not swinging. Hold onto the pulley wheel so that it cannot rotate. This will keep the masses from moving. Click the collect button at the top of the page to start data collection. Release the pulley wheel. The masses will begin to move and data collection will start.
7. Select the region of the graph where the velocity was increasing at a steady rate by left clicking and holding the mouse button as you drag across the region of interest. After the region is selected it should be shaded gray. Click the linear fit button (the icon at the top that says  $R=$ ) to fit a line to the data. Record the slope of this line, which is the acceleration, in the data table.
8. Repeat Steps 5–8... continue to move masses from  $m_1$  to  $m_2$  in 2g increments, **changing the difference between the masses, but keeping the total constant.** Repeat until you get five

different combinations recorded in the table below. Note: The light side is getting lighter and the heavy side is getting heavier each time.

**Data Table**

Trial	$m_1$ (grams)	$m_2$ (grams)	$m_{\text{diff}} = m_2 - m_1$ (grams)	$m_{\text{diff}}$ (kilograms)	Force or $g(m_1 - m_2)$ (Newtons)	Acceleration ( $m/s^2$ )
1						
2						
3						
4						
5						

## ANALYSIS

- For each trial, calculate the difference between  $m_1$  and  $m_2$ . Enter the result in the column labeled  $m_{\text{diff}}$ . Convert this value into kilograms and list it in the next column over.
- For each trial, calculate the force,  $g(m_1 - m_2)$  where mass is in kg and  $g=9.803 \text{ m/s}^2$ .
- Open EXCEL. Enter the data for acceleration and force into a table. Make a scatter plot graph of force vs. acceleration (acceleration goes on the x axis). Like you did on the first lab (the speed of the bubbles), insert a linear trend line through the data. Be sure to display the equation of the trend line and  $R^2$  value. Also be sure to insert appropriate labels on your axes and label your graph. Print a copy of the graph for each of your group members.
- Write down Newton's second law as an equation. Use symbols not words.
- Apply Newton's second law to the Atwood machine. To do this, consider the following:
  - The net force on the Atwood's machine is the difference between the weight ( $W=mg$ ) of the heavy side and the weight of the light side. Write down this difference in weight using symbols like  $g$ ,  $m_1$  and  $m_2$ .
  - Write the Newton's second law equation again (as you did in #4) replacing the net force symbol with an expression for the weight difference (again, using only symbols as in a). How much mass is accelerated? Write this as a symbol or symbols and make this replacement in the Newton's second law equation.

6. The general equation of a line is  $y=mx+b$ . For our graph, assume  $b$  is zero so  $y=mx$ . Acceleration is plotted on the  $x$ -axis and  $(g \times m_{\text{diff}})$  is plotted on the  $y$ -axis. Given these facts, what is the equation for the line we plotted in terms of acceleration and  $g \times m_{\text{diff}}$ ?
  
7. Compare your expression for the plotted line from #6 above to the equation that you developed based on Newton's second law in #5. What should the slope of your line represent?
  
8. Refer back to #3. What is the numerical value of the slope of the graph you generated in Excel? What value do you think that the slope should have? Calculate a percent error between the two. Show your work.
  
9. Use your answer to #5 above to find an expression for the acceleration of in terms of  $m_{\text{diff}}$ ,  $m_{\text{total}}$ , and  $g$  (solve for  $a$ ).
  
10. Use the expression for acceleration that you developed in #9 to calculate the expected acceleration for your largest mass difference. Compare this with your experimentally measured acceleration for that mass difference. What is the percent difference between these values?