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LAB #3: UNIFORMLY ACCELERATED MOTION

OBJECTIVES:

To study the motions of two systems that have constant acceleration. One that is in free-fall and one that has a smaller acceleration.

EQUIPMENT:

Equipment Needed	Qty	Equipment Needed	Qty
Picket Fence Board	1	Atwood's Machine	1
Photogate / Pulley System	1	Pasco Mass and Hanger Set	1
Mouse Pad	1	Table Clamp w/ Rod	1
Double-V Clamp	1	Ruler	1
Linear Graph Paper on Front Desk		Capstone on computer	

SAFETY REMINDER • Follow all safety instructions. • Keep the area clear where you will be working and walking.	**THINK SAFETY** **ACT SAFELY** **BE SAFE!**

INTRODUCTION

In this lab you will be using the computer to take data for two experiments, the "picket fence" board as it falls through a photogate, and an accelerating Atwood's machine. This data will then be graphed and analyzed.

PROCEDURES

Answer all of the questions on this handout.

When an object has a constant acceleration, its position, "x", depends on its acceleration, "a", the time it has been moving, "t", its initial position, "x_o", and its initial velocity, "v_o". That is

$$x = x_o + v_o\, t + (1/2)\, a\, t^2\ .$$

It velocity, "v", depends on its acceleration, "a", the time it has been moving, "t", and its initial velocity, "v_o". That is

$$v = v_o + a\, t\ .$$

We can see that if the velocity is graphed as a function of the time, the slope will be the acceleration.

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If the instantaneous position is measured, the instantaneous velocity and acceleration can be approximated by looking at small changes in position and velocity, respectively. That is

$$v_{av} = \Delta x \,/\, \Delta t \text{ and } a_{av} = \Delta v \,/\, \Delta t \,.$$

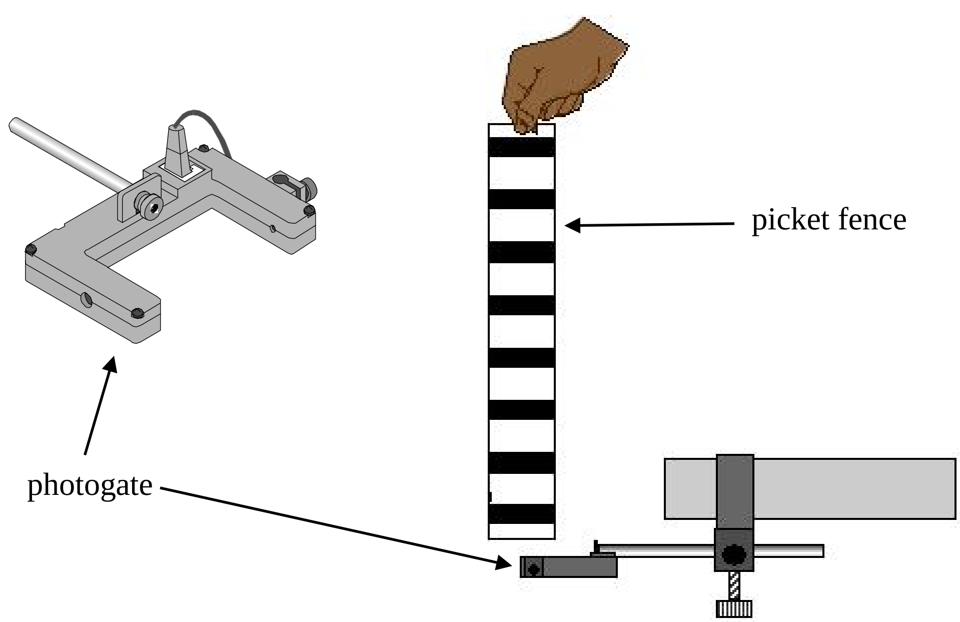
Rather than doing this by hand, we will let the computer do it for us. In the first case we will look at the motion of a "picket fence" in free-fall. The picket fence is a plastic rectangle that has a series of black and clear stripes on it. As the picket fence falls through a photogate, the black stripes will block the photogate, and the times when this occurs will be measured by the computer. The distance between leading edges of the black stripes is 5.00cm . Using this as the distance traveled between each time, the computer will calculate the fence's velocity and acceleration.

PART 1: Computer Setup for the Picket Fence

<u>Do not turn on anything, yet.</u> Locate the 850 Universal Interface on your lab bench or on the bench next to the wall. A data cable connects the interface to your group's desk top computer. That will be the computer you will be using for this lab. Turn on the interface, and then make sure the computer is on. For instructions on setting up the Picket Fence experiment, refer to the "Capstone Experimental Setups & Procedures" document, which is available on the CLAPHAST web page, http://sites.gsu.edu/claphast. The equipment setup is described below.

PART 2: Picket Fence Measurement

Attach the photogate and clamp to the table as shown in the figures below, so that the photogate is held horizontally, and the picket fence can be dropped through its arms. Place the mouse pad on the floor directly below the photogate, so that the picket fence will not hit the bare floor. Your picket fence may have seven or eight black bars on it.



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Practice dropping the picket fence through the photogate arms so that the fence drops straight down without touching the photogate. When you are ready to take data, push the "Start" button, drop the fence, then push the "Stop" button. There is no need to try to start and stop too quickly, it is more important that you get all of your data points. You should get a number of data points that is one less than the number of black strips on your picket fence. This is because the data point for the first strip is not included. Enter your data into the Table #1. Times for the velocity and acceleration columns are average times of two data points in a preceding column.

Table #1

Position		Velocity		Acceleration	
t (s)	x (m)	t (s)	v (m/s)	t (s)	a (m/s^2)
			Average acceleration =		

Determine the average of the acceleration values and enter it into the Table #1.

1. What is your average value for the acceleration?

2. What is the percent error between this value and the accepted value for the acceleration due to gravity?

The setup document describes how to fit the graph to a straight line. Do this.

3. What is the slope of the velocity vs. time graph?

4. What is the percent error between this value and the accepted value for the acceleration due to gravity?

5. What is the percent difference between your average value for the acceleration and the slope of the velocity vs. time graph?

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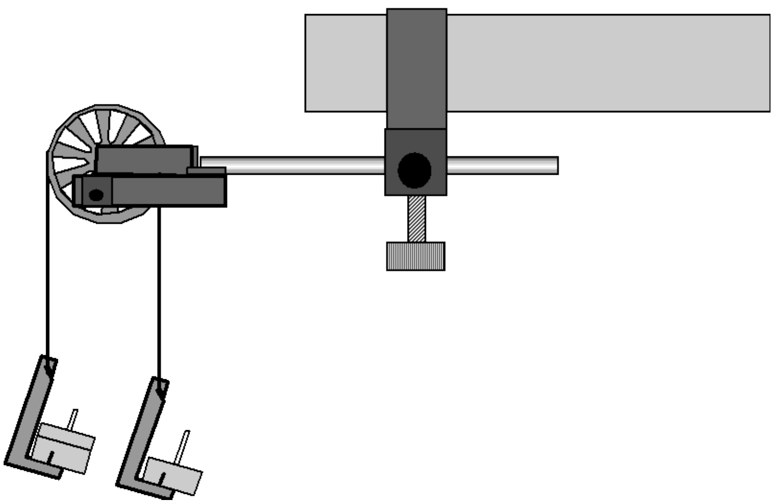
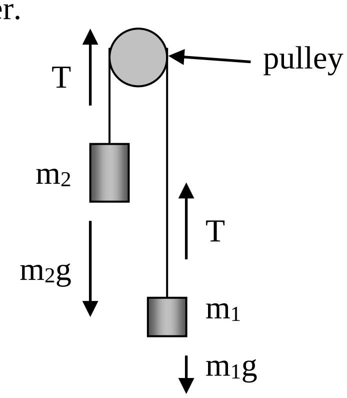
Print copies of your Capstone tables and graphs and turn them in with your lab.

PART 3: Atwood's Machine

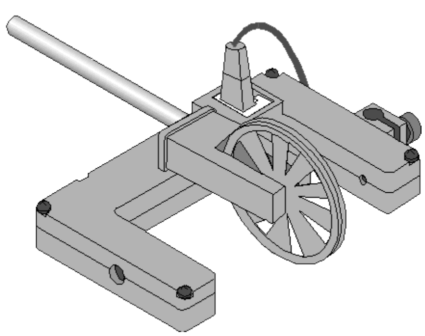
Attach the pulley to the photogate and hang the string with two mass hangers over the pulley as shown in the figures below. You might need to cut the string, or get a new piece, so that the masses will be able to accelerate over a long enough distance before one hits the floor. Also, make sure that m_2 will rest on the floor without m_1 hitting the pulley.



This system, as pictured, is called an Atwood's Machine. Define the two masses as m_1 and m_2. When one mass is larger than the other, we will let m_2 be the larger.



Consider the force diagram for the Atwood's machine at the right. We can see that if $m_2 > m_1$, the masses will accelerate counterclockwise, that is, m_2 will accelerate downward and m_1 will accelerate upward. We will therefore define the motion for m_2 as positive downwards and m_1 as positive upwards. Notice that whatever amount m_2 moves down will be the same amount m_1 moves up, so the magnitude of their accelerations will be equal. Also, if we ignore friction, the tension in the string will be the same on both sides of the pulley. So, applying Newton's Second Law to each side yields



$$m_2\, g - T = m_2\, a \quad \text{and} \quad T - m_1\, g = m_1\, a\ .$$

Solving for “a” we find

$$a = (m_2 - m_1)\, g\, /\, (m_2 + m_1)\ .$$

Notice that when $m_2 = m_1$, $a = 0$, which makes sense physically.

To measure the acceleration of our Atwood’s Machine, the photogate will measure the rate at which the pulley rotates. It will then calculate how fast the masses are moving.

PART 4: Computer Setup for the Atwood’s Machine

Make sure you have printed out any important tables and graphs, then close down Capstone. Restart Capstone and refer to the “Capstone Experimental Setups & Procedures” document for setting up the Atwood Machine Experiment.

We are going to take two sets of data with the Atwood’s Machine, one in which we will use a constant total mass, i.e. “$m_2 + m_1$ = constant” , and the other in which we will use a constant mass difference, i.e. “$m_2 - m_1$ = constant” .

PART 5: Atwood Machine Measurement, Constant Total Mass

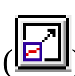
Add enough mass onto the mass hangers so that “m_1 = 113g” and “m_2 = 117g” . Remember that the mass of each hanger needs to be included.

6. What is the theoretical acceleration given these values for m_1 and m_2?

Raise m_2 until it is just below the pulley. Get ready to click on the “Start” button in Capstone.

Release m_2, click the “Start” button, just before m_2 hits the mouse pad on the floor click the “Stop” button (the “Start” button turns into a “Stop” button after it is pressed).

Look at the graph of your data. If you did not start and stop the measurement correctly, your data will not look like a straight line. Do more trials until you produce a set of data points that form a straight line.

Click the “Scale to fit” button () to fit your graph to the available space. Click on the “Curve fit” button (
) and choose the “Linear Fit” option to determine the equation of your line.

7. What is the experimental acceleration of your system, i.e. what is the slope of your line?

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8. What is the percent error between your theoretical and experimental accelerations?

Transfer 2g from m_1 to m_2 and repeat the experiment. Complete Table #2.

Table #2

Run	m_1 (kg)	m_2 (kg)	a_{theor} (m/s^2)	a_{exp} (m/s^2)	% error
#1	0.113	0.117			
#2	0.111	0.119			
#3	0.109	0.121			
#4	0.107	0.123			
#5	0.105	0.125			

PART 6: Atwood Machine Measurement, Constant Mass Difference

Change the masses so that "m_1 = 105g" and "m_2 = 115g" . Remember that the mass of each hanger needs to be included.

9. What is the theoretical acceleration given these values for m_1 and m_2?

Repeat the experiment.

10. What is the experimental acceleration of your system?

11. What is the percent error between your experimental and theoretical accelerations?

Add 5g to both masses and continue the experiment, filling Table #3.

Table #3

Run	m_1 (kg)	m_2 (kg)	a_{theor} (m/s^2)	a_{exp} (m/s^2)	% error
#1	0.105	0.115			
#2	0.110	0.120			
#3	0.115	0.125			
#4	0.120	0.130			
#5	0.125	0.135			

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12. Do your results for the Picket Fence agree with what you would expect theoretically? Explain.

13. Do your results for the Atwood Machine agree with what you would expect theoretically? Explain.

14. Do your percent errors for the Atwood Machine indicate anything about the experiment? Explain.

15. Do you think it was valid for us to assume that there was no friction in the Atwood Machine? Explain.

Clean-Up

Replace all the equipment to the table top. Replace all of the masses to their correct location in the "Mass and Hanger Set" box. Replace the photogate and pulley to their box.