Freefall of a Picket Fence

Introduction

A Picket Fence is a clear plastic strip with uniformly spaced opaque bands. Each opaque band blocks the photogate beam, and the time from one blockage to the next becomes shorter as the velocity of the falling Picket Fence increases. Using the known distance between the leading edge of each band, and the time interval between photogate blocks, the student calculates the average velocity of the Picket Fence for each interval. The slope of the graph of average velocity versus time gives the acceleration of the falling object.

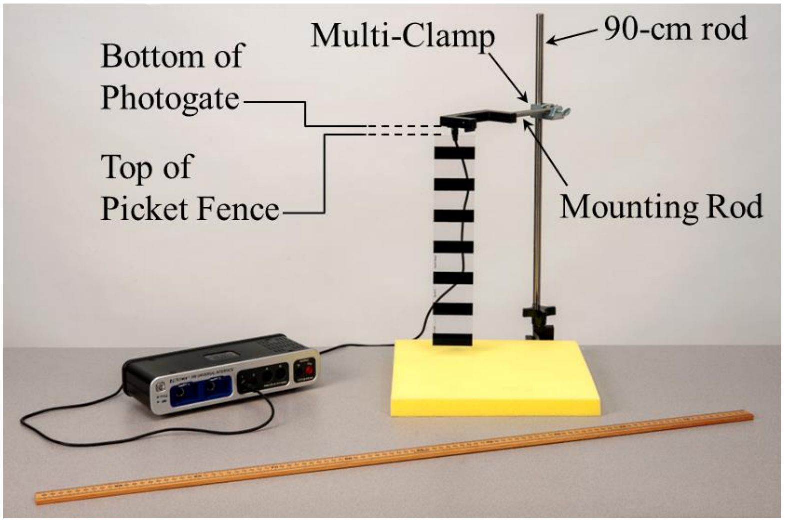

Figure 1: Picket Fence Setup

Equipment

Qty	Items	Part Number
1	Photogate	ME-9498A
1	Picket Fence	ME-9377A
1	Mounting Rod	SA-9242
1	Large Table Clamp	ME-9472
1	Multi-Clamp	ME-9507
1	Rod, 90 cm	ME-8738
1	No-Bounce Pad	SE-7347
Required, but not included:		
1	Meter Stick (Only 1 needed)	SE-8827
1	550 Universal Interface	UI-5001
1	PASCO Capstone software	

Set-up

1. As shown in Figure 1, fasten the Table Clamp and the 90-cm Rod to the edge of the table. The Mounting Rod screws directly into the side of the Photogate. Then use the Multi-Clamp to fasten the Mounting Rod + Photogate to the vertical 90-cm Rod.

2. Position the yellow No-Bounce Pad (see Figure 1) on the table to protect the falling Picket Fence when it reaches the table.

3. Later, when you drop the Picket Fence through the Photogate, it should pass all the way through before hitting the pad. Adjust the Photogate height as shown in Figure 1, so that when standing vertically on the pad, the top of the Picket Fence should be below the bottom of the Photogate.

4. Plug the Photogate cord into Digital Input 1 of the interface.

5. In Capstone software, open Hardware Setup and connect the Photogate.

   Then, open Timer Setup and follow the steps to set up a Pre-Configured Timer, Photogate Ch 1, Picket Fence. Select the following measurements to be visible: Block Event Times, and Speed. Flag spacing is 0.05, with units of m.

6. To practice dropping the Picket Fence through the Photogate: Position the bottom of the Picket Fence just above the Photogate, as shown in Figure 2.

   Hold the Picket Fence at the top between your thumb and forefinger, as shown in Figure 3. The Picket Fence must hang vertically, so that when it is released, it will fall straight without rotating.

   Note: The procedure is easier if one person handles the Picket Fence and another operates the computer.

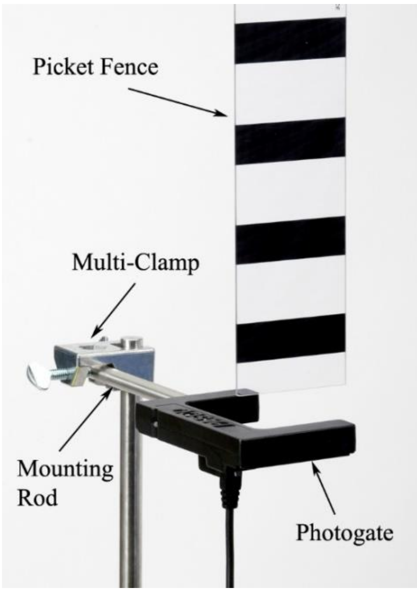

Figure 2: Picket Fence Initial Position

Figure 3: Hold in Center

Taking Data

1. On the Picket Fence, use the meter stick to measure Δx, the distance from the leading edge of one band to the leading edge of the next. You can measure over several bands to get a more accurate value of Δx. Record your value.

2. Make a table and put Block Event Times for the Picket Fence in the first column. Leave the second column blank for now.

   Beginning at time 0 when you click Record, the Block Event Times are the instants that each of the seven bands on the Picket Fence break the Photogate beam.

3. Start recording data, and then drop the Picket Fence through the Photogate. Stop recording data. You should see seven Block Event Times values appear in the data table.

   If the Picket Fence hits the Photogate, or if it rotates too much, you should delete that run and take another run.

Calculations

1. In the second column of the table, create a user-entered data set named "Δt" with units of seconds. (Remember that you can get a Δ symbol in Capstone by right-clicking where you are typing.)

   Calculate time interval Δt between successive Block Event Times. For example, the first time interval is $\Delta t = t_2 - t_1$, the second is $\Delta t = t_3 - t_2$, and so on. Enter the results into the Δt table column. You will end up with only six time intervals in your table.

   Note that you may have to increase the number of decimal places in each column to see the values clearly. You can do this using the tool at the top of the graph.

2. Create a third column and in it, create another user-entered data set called "Average t" with units of seconds.

   For the first time interval $\Delta t = t_2 - t_1$, find the instant halfway between t_2 and t_1, or the average time for that interval:

$$\text{Average t} = \frac{t_1 + t_2}{2}$$

   Calculate this value and enter into the Average t column. Repeat for all the other time intervals. You should end up with six Average t values in your table.

3. Create a fourth column with another user-entered data set called "Average v" with units of m/s.

   Calculate the average speed of the Picket Fence for the first time interval ($\Delta t = t_2 - t_1$):

   $$\text{Average v} = \frac{\Delta x}{\Delta t}$$

   Enter your calculated value into the Average v column in the table. Repeat for each of the other time intervals. You will end up with six average speeds in your table.

   Note that Average v for the first time interval ($\Delta t = t_2 - t_1$) corresponds neither to t_2 or t_1, but approximately to the Average t, the instant halfway between t_2 and t_1.

Average v vs. Average t

1. To see how Average v increases with time, create a graph of Average v vs. Average t. You may want to turn off the connected lines in the graph and perhaps make the data points bigger. Turn on the Curve Fit from the graph toolbar, and select Linear fit. Record the slope.

   What is the physical meaning of the slope? Does it have units? What is the uncertainty in your value?

2. Compare the slope of your graph to the accepted value of g using the percent error calculation:

   $$\%\ \text{Error} = \frac{\text{Measured} - \text{Accepted}}{\text{Accepted}} \cdot 100$$

   Was your value too high or too low? What might account for that?

Average Acceleration Over Several Drops

1. In the previous sections, you used the Photogate to measure only the time of block, and then you calculated the average speeds and average times by hand. In Capstone, similar calculations can be done automatically for you.

   In Capstone, create a graph of the Picket Fence's Speed vs. Time (NOT the Picket Fence's Block Event Times). This is similar to your Average v vs. Average t graph, but uses values that the software calculates automatically for you.

2. In Capstone, create a table. In the first column, create a user-entered data set called "Acceleration" with units of m/s^2. Delete the second column.

3. Start recording data, and then drop the Picket Fence through the Photogate as before. Stop recording data.

4. The speed vs. time data for this run will be graphed. Select a Linear curve fit to find the acceleration as before. Record this acceleration value in the table.

5. Repeat several times, recording each acceleration value in the table.

6. On the table, use the toolbar to turn on Statistics, and show the Min., Max., and Mean. Record the mean value with an estimated uncertainty based on the Min. and/or Max. value.

7. How does the mean acceleration value compare to the accepted value of g?