Computer-Assisted Measurement of g

Objective

The purpose of this experiment is to introduce you to computer-assisted measurements, which you will use in several future experiments. This experiment should also reinforce concepts of velocity-time graphs and objects in free fall.

Materials

1. Cushion or pad (foam)
2. Pasco 850 Interface
3. Photo-gate and stand
4. Picket Fence

Procedure

Getting Set Up

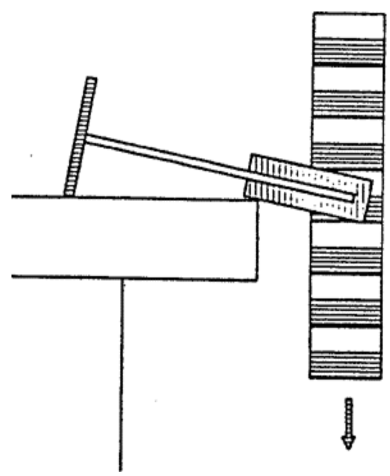

Figure 1: *Picket Fence*

Your measurements will make use of a computer timer that detects when the infrared beam of a photogate is broken. Attach the photogate to its stand in such a way that, with the stand upright, the open side (the gap) points up. Lay the photogate stand on the table so that the photogate gap is nearly horizontal and hanging over the edge of the table as far as possible (see Figure 1). Plug the photogate cable into digital input #1 of the Pasco interface. Double-click on the "Pasco Capstone" icon on your desktop. Double click on "Hardware Setup" (in the "Tools" window panel on the left side of screen). Click on digital input #1 on the interface and select "Picket Fence" from the drop-down menu. This should place a picture of a photogate and picket fence in digital input #1 of your interface. Double-click on "Table" on the "Displays" window panel on the right side of the screen. A 2-column table will appear on your screen. Click "Select Measurement" in the first column and choose "Time". Repeat this for the second column and choose "position". The times recorded on this table will be a list of the time-in, t_{in} values (the time that each new black stripe enters the photogate).

Collecting Data and Calculating g

Place a cushion on the floor below the photogate to catch the fence. Gently hold the fence by one end, and let it hang vertically just above the photogate gap. The idea is to have it fall through the gap without touching anything. This may take several tries. When you are ready, click on the "Record" button in the "controls" window panel at the bottom of the screen. Drop the fence. Then click "Stop" to stop the timer. If you are not satisfied with this data, do it again. When you are satisfied with the data, you are to create a data table of t_{in}, Δt, t_{mid}, and $\overline{v}$ values (similar to the sample data provided in Table 1).

t_{in} (sec)	Δt (sec)	t_{mid} (sec)	$\overline{v}$ (m/s)
.0030	—	—	—
.0620	.0590	.0325	.847
.1132	.0512	.0876	.976
.1574	.0442	.1353	1.13
.1972	.0398	.1773	1.26

Table 1: Sample Table for Picket Fence

You will enter in your t_{in} values just as they appear from your picket fence-drop data. Each Δt value will be the difference between the corresponding t_{in} values. For example, using the sample data in Table1,

$$\begin{aligned}\Delta t_2 &= t_{in,2} - t_{in,1} \\ &= 0.0620s - 0.0030s \\ &= 0.0590s \\ \Delta t_3 &= t_{in,3} - t_{in,2} \\ &= 0.1132s - 0.0620s \\ &= 0.0512s\end{aligned}$$

...and so on. You will compute average speed, $\overline{v}$, as distance traveled (from the start of one stripe to the start of the next stripe, $d = 0.050m$) divided by Δt. For example,

$$\begin{aligned}\overline{v}_2 &= d/\Delta t_2 \\ &= (0.050m)/(0.0590s) \\ &= 0.847m/s \\ \overline{v}_3 &= d/\Delta t_3 \\ &= (0.050m)/(0.0512s) \\ &= 0.967m/s\end{aligned}$$

Because the acceleration is constant, we may relate the average velocity $\overline{v}$ to the instantaneous velocity v at a particular time during each time interval Δt. Specifically, the instantaneous speed v_2 during time interval Δt_2 is equivalent to the average speed $\overline{v}_2$ at time $t_{mid,2} = (t_{in,1} + t_{in,2})/2$ (see your Physics textbook). Therefore, in our case, halfway through each time interval, the instantaneous speed is known. For example, halfway through the time interval Δt_2, the instantaneous speed is v_2; halfway through the time interval Δt_3, the instantaneous speed is v_2. The times associated with these instantaneous speeds are recorded in column t_{mid}.

After completing the table, neatly graph $\overline{v}$ vs t_{mid}. Compute the slope of the graph to obtain the average acceleration. Is this a reasonable value for g?

Computer Analysis of the Data

Now let's see that the computer can do all of this work for us. Your data should still be on the screen. On the "Displays" window panel, double-click on "Graph". Click on "Select Measurement" on the vertical axis of your graph and choose "Speed". You should now see a very similar looking graph to the one you just plotted by hand. At the top of your graph click on the "Curve Fits" tool. Choose "Linear". This is the computer's attempt to fit your data to a linear equation. In the box that now appears on your graph you should see a value for m. This is the slope of the fit-curve.

Does this computer-calculated result agree with the one obtained from your hand-plotted graph? If not, try to decide why. Also comment on possible causes of differences between your measured values and the accepted value of $9.8m/s^2$. In the box of linear fit results on your graph you should see a value for r. The r-value gives a measure of how well your data fit a straight line—that is, how nearly constant the acceleration was. A perfect fit would give exactly r = 1. If you have r very near 1, you should see that all data points are on or very near the straight line. Record this r-value.

Repeat

Repeat the data collection and computer analysis nine additional times (remember to press "Stop" then "Record" in between consecutive data runs). You should now have 10 (probably slightly differing) values of g. You view measurement from the run of your choice by selecting the corresponding run number from the drop-down of the "Data Summary" tool. Determine the average and standard deviation of this set of values[1]. Treat the average value, $\bar{g}$, as your experimentally determined value of Earth's acceleration due to gravity, and use the standard deviation, σ_g, as the "error bars". Does the accepted value of g fall within the range ($\bar{g}$-σ_g, $\bar{g}$+σ_g)? If so, you may reasonably claim that your value of g agrees with the accepted value; if not, determine why (and don't simply say "human error"), and take it seriously—really think about it.

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[1] See Data Analysis for General Physics.