The purpose of this lab is to measure the gravitational acceleration constant $g$ by measuring the rate at which a falling object increases its speed. You also learn the use of computerized lab equipment, which is helpful for later experiments, too.

Important! You need to print out the 2 page worksheet you find by clicking on this link [http://skipper.physics.sunysb.edu/~physlab/Fall2016/AccUpdatedLab2worksheet.pdf].

If you need the .pdf version of these instructions you can get them here [http://skipper.physics.sunysb.edu/~physlab/Fall2016/AccUpdatedLab2manual.pdf].

Video

Equipment

- computer for taking and recording data
- photogate (combined light source and detector assembly)
- interface box
- clear plastic ruler with periodic opaque regions made with masking tape
Measurement of the gravitational acceleration g by measuring velocity vs. time

In this lab, you will drop a ruler through a photo gate. From this you can infer the rate at which the ruler will accelerate due to the earth's gravitational force. The clear plastic ruler is covered at regular intervals with pieces of masking tape that block the light beam in the photogate. The detector in the photogate creates light “on” and light “off” signals that turn on and off a timer run by computer software. This creates time intervals that are recorded by the computer and displayed on the monitor. Using the distance (that you measure) between successive pieces of masking tape and these time intervals, software instructs the computer to calculate the average velocity of the ruler during each of these time intervals during its fall. The results can be displayed graphically on the monitor in various instructive ways.

Using the photogate and computer

You need to know the length \( d \) between the leading edges of two successive pieces of tape, i.e., the length of one opaque region (piece of tape) plus one clear region.

To be more accurate, measure the distance \( D \) from the leading edge of the first piece of tape to the leading edge of the last piece of tape on the ruler. If there are \( N \) such “picket pairs” (tape + clear regions) on your ruler, you get the average value of \( d \) by dividing \( D \) by \( N \): average value of \( d = \frac{D}{N} \).
After measuring $D$ and determining $d$, you need also to estimate values for their respective uncertainties. Things you should take into account are the accuracy of your measurement tool and how straight your masking tape is. Fill in the table on your worksheet with your values for $D$, $d$ and their respective uncertainties.

Now, connect the photogate output to the interface box by plugging the cable from the photogate into the top socket (labeled “DIG/SONIC 1”) of the black interface box ("LabPro"). Test the photogate: block/unblock the photogate light beam with your finger and see the red light on the cross bar of the photogate turn on/off.

Get the computer ready for data taking:

- Turn on the computer and check the system by following these instructions: double click the icon Exp2_xva_t. A window with a spreadsheet on the left (having “Time, Distance, Velocity, Acceleration” columns) and empty graphs on the right (distance, velocity and acceleration vs time) should come up. On top is a window “Sensor Confirmation”. It should show the following kind of information. If it's not in exactly the form shown just below, don't be concerned. You just want to make sure that the Photogate sensor is connected to the LabPro interface and working with the computer.

<table>
<thead>
<tr>
<th>Sensor Specified In File:</th>
<th>Sensor To Set Up:</th>
<th>Where:</th>
<th>Use:</th>
</tr>
</thead>
<tbody>
<tr>
<td>✔ Photogate</td>
<td>Photogate</td>
<td>DIG1 on LabPro</td>
<td>✔</td>
</tr>
</tbody>
</table>

- Click OK

- If you don’t see the above do the following:
  - Click Experiment→Set Up Sensors→Show All Interfaces→DIG/SONIC1: you can check the photogate by blocking it and seeing “Unblocked’ go to “Blocked”.
  - Click “Close”

- Click Data→User Parameters: the window “User Parameters” should come up. Enter your value for the distance $d$ into the program in the value box.

<table>
<thead>
<tr>
<th>Name:</th>
<th>Value:</th>
<th>Units:</th>
<th>Places:</th>
<th>Increment:</th>
<th>Editable:</th>
</tr>
</thead>
<tbody>
<tr>
<td>PhotogateDistance1</td>
<td>your value of $d$</td>
<td></td>
<td>4</td>
<td>1.0000</td>
<td>✔</td>
</tr>
</tbody>
</table>

- Click OK
Click Experiment→Start Collection. You should see “Waiting for Data” on the right hand side graph.

While the message “Waiting for data” is on, hold the ruler just above the photogate (with the lowest edge of the lowest piece of masking tape kept just above the light beam) and then release the ruler so that it drops straight down through the photogate. If you do this well, each piece of tape on the ruler will block the path of the light beam in the photogate and each clear region will allow the light to pass through. Make sure that the ruler is aligned vertically before you drop it, so that it is oriented perpendicular to the light beam during its fall. After the ruler has fallen through the photogate you should see the collected data on the screen: Time, Distance, Velocity, Acceleration. After a little while the corresponding graphs should appear on the right side of the screen. If you waited too long before dropping the ruler, the “Waiting for Data” message disappears. This means you must restart the procedure. Any time you want to repeat your measurement simply restart.

On the measurement program you should have at least 5 velocity values and a straight line velocity versus time graph; straight means without a “kink” on the right. If you do not see a straight line displayed, repeat the measurement.

Copy the time and velocity values into the table on your worksheet.

Make sketches of distance versus time, velocity versus time and acceleration versus time in the grid areas on your worksheet. Label all axes, units and scales. Make sure your vertical axes start their scales at zero. If a graph on the screen does not start from zero, click on it, click Options→Graph Options and choose “Autoscale from 0”.

Using a graph to find the value of g

You are now going to make a plot of \( v \) versus \( t \) to determine a value for \( g \). In this plot you need to have estimates for the uncertainty in \( v \). The uncertainty in \( v \) comes from the uncertainty in your measurement of \( d \). In the online pretest for Lab 2, you worked out how to relate the uncertainty in \( v \) to the uncertainty in \( d \). Having done this before coming to do this lab, you should be able to complete the table on your worksheet and then fill in the \( y \) error box on the plotting tool. You should assume that errors in \( t \) are too small to worry about (the computer is very accurate, or at least much more accurate than you or I are at using a ruler to measure a length). This means you do not need to enter anything in the \( x \) error boxes, so you should select the option that there are errors only in \( y \). Do you think this graph should be a “constrained, linear fit” (see Lab 1) that is forced to go through the origin \((0,0)\) (or, in other words, at \( t=0 \) you should have \( v=0 \))?

Go ahead and make your plot of \( v \) versus \( t \). The slope of the graph should be equal to \( g \), the magnitude of \( g \)? How does the value you obtain compare to accepted value of \( g = 9.81 \text{ m/s}^2 \) ?

**Using a graph to find the value of g**

**What kind of errors are you entering below?** None  
(Do not include \((0,0)\) in your list of points below, it will mess up the fit.)

| x axis label (include units): | | y axis label (include units): |
| x1: +/- | y1: +/- |
| x2: +/- | y2: +/- |
| x3: +/- | y3: +/- |
| x4: +/- | y4: +/- |
| x5: +/- | y5: +/- |
| x6: +/- | y6: +/- |
| x7: +/- | y7: +/- |
| x8: +/- | y8: +/- |
A different approach to getting g and its uncertainty

In the approach taken above, you estimated the uncertainty in g based upon the propagation of what we expected to be the most significant source of experimental error. Another approach you can take is to make several measurements, which you can do by using the built-in fitting tool in the measurement program. This tool, unlike the one you just used, will not take into account the uncertainties in your input values. Instead, you must estimate the uncertainty in your measurement using the approach used in Lab 1 (Eq. (E.5b)) to estimate the uncertainty in an average value of a measured quantity.

You are still going to drop the ruler through the photogate, just as you did before. Now, to get your desired value from the computer, you should click the graph, then click Options→Graph Options and check Velocity, and click Done. Then click Analyze→Linear Fit. Read the slope of the plot from the popup window that displays the results of the fit. Repeat this 5 times and enter your results in the table on your worksheet. Now use, respectively, Eqs.(E.5) and (E.5b) from Lab 1 to calculate the average value of g and the uncertainty in the average value of g. Compare these results to both the accepted value of g and your previous, measured value of g. How do the uncertainties you have estimated for the two different approaches compare to each other? Which one do you think is a better estimate? Why?

Demonstration of non-zero initial velocity

In this last part, see what happens to the initial (“initial” is the first time the light beam in the photogate beam is blocked) velocity $v_0$ if the ruler is dropped from “far above” the photogate (see the video) than when you dropped it from “just above” the photogate. Hold the ruler a few inches above the photogate and then drop it carefully it travels through the photogate as before. Now look at the computer-generated plot of velocity versus time and record the initial velocity $v_0$ from the plot on your worksheet. Is your initial velocity greater or less than the one you recorded earlier? What do you expect it should be?

Finishing up

After you think you have done all required parts of the experiment, make sure that you have filled in your worksheet and thought about all the questions that are asked in this lab manual. Let one of the TAs know that you are ready to discuss the results from experiment. This will begin the “exit interview” process that the TA (either the primary TA or the secondary TA) will use to determine your grade for the in-lab part of your work. (Recall that the in-lab part is worth a maximum of 65 points, but this depends on your Primary TA’s after-lab grading of your Lab worksheet, which will determine how many of those 10 points you will get. S/he will collect it before you leave. As judged by the TA from your exit interview, “satisfactory” work will earn you 55 of the 65 points. Unsatisfactory work will earn you 35 points, unless you did not bring the Lab 2 worksheet with you, in which case you’ll automatically earn only 25 points. “No serious attempt”, which means that you came to lab unprepared and didn’t accomplish anything worthwhile in the lab, will result in your receiving zero points for the in-lab work. The online, lab pretest is worth a maximum of 35 points.)

Note that the TAs will want to see that you understand the concepts behind what you are doing in the lab as well as the actual experiment itself. After a discussion with you they may either tell you that you’ve done a good job, or, if there is a problem with your data or your analysis of your data, they may ask you to redo some of the work. Therefore, you don’t want to wait until the last few minutes of the lab session for your exit interview.

Before you leave please make sure that all equipment is left in the way you would hope to find it if you were in the next section!