Physics I – Laboratory #1

Falling Projectiles and Dimensional Analysis

INTRODUCTION

One can use a simple dimensional analysis to discover the relations between how long a projectile falls and the height from which the projectile is released. Namely, the time a projectile falls is proportional to the square root of the height from which it falls:

$$t \propto \sqrt{h}$$

We will be using the Vernier sensors and equipment to test this relation.

OBJECTIVES

- Collect timing data for a falling projectile
- Use multiple trials to estimate the timing uncertainty.
- Determine the best fit to the fall times as a function of height.

MATERIALS

Computer
Vernier computer interface
Logger Pro
Ball/rubber stopper/other projectile
Two Vernier Photogates
Two Lab stands

PRELIMINARY QUESTIONS

1. Make a sketch of your prediction for how falling time depends on height. Describe this graph in words.
2. What constitutes a "good drop" for each trial of the falling projectile?

PROCEDURE

1. Connect the two photogates to two different DIG/SONIC channels of the interface. Plug in the interface and connect it to a computer via a USB cable.
2. Mount the two photogates onto a single lab stand, separated by approximately half a meter. *Make sure that the photogate plugged into channel 1 is on the top.* Measure and record the separation between the midline of the photogates (i.e. where the sensors are) as best you can, making an estimate of (and noting) the uncertainty with which you think you can measure the separation.
3. Open Logger Pro. Within Logger Pro, go to File > Open, and select Logger Pro > Experiments > Probes & Sensors > Photogates > Pulse Timer-Two Gates.cmbl
4. Click ▶ Collect in Logger Pro.
5. Drop the projectile 10 times, making sure it passes through both photogates on each fall (the little red LED on the back of the Photogate will light up when it's blocked). Record in your notebook the 10 fall times reported by Logger Pro. Estimate how accurately you think you can measure the fall time. You can either do this formally (i.e. calculating the standard deviation) or informally (i.e. by looking at the variation in fall times). Click ■ Stop to stop collecting data.
6. Next, increase (or decrease) the vertical distance between the two photogates (*Hint: putting one photogate on a lab stand hanging over the edge of the lab bench and the other on the floor will help you to get extra height*). Measure and record the vertical distance between the two photogates.

7. Click ▸ Collect and drop the projectile through both photogates again, recording the fall time between the two photogates. Repeat this measurement two more times, making sure you have at least three trials for each height. Click ■ Stop.
8. Repeat steps 6 and 7 at least four more times, resulting in a total of at least 6 different heights over a range of different distances; it is strongly recommended that your distances range from relatively small (~5 cm) to fairly large (1m or more).
9. Create a plot in Logger Pro of fall time (for a specific height trial) vs. height. *See guide at bottom of lab for how to plot in Logger Pro. Think very carefully about which quantity should be on the X-axis and which should be on the Y-axis.* Print the plot out and paste it in your lab notebook. Draw a trend line, if appropriate. How closely does the graph match what you sketched at the beginning of the experiment? If it differs, why do you think it differs?

ANALYSIS

1. Given your estimate of the measurement uncertainty in Step 2 and the accuracy you determined in Step 5, how confident are you that the times you measured in the later steps (i.e. at a variety of heights) are significantly different? Explain.

2. Do your results confirm or refute (or neither) the simple relation determined from dimensional analysis?

3. What other forces might affect the time over which a projectile falls? Are those effects considered here? How big of an effect do you think those forces have on the projectile? Can you set quantitative limits? Explain.

EXTRA STUFF

Fall time is proportional to the square root of height. This means that $t = C\sqrt{h}$, where C is some constant. What is the value of that constant? What must be the units of that constant?

PLOTTING IN LOGGER PRO

- Disconnect the Vernier Labquest Mini interface from the computer by unplugging the USB cable from the interface.
- Within Logger Pro, click File > New
- Right click on 'X' > Column Options, and rename it to "Height," change units to "m"
- Right click on 'Y' > Column Options, and rename it to "Time," change units to "s"
- Add data points in the table (spreadsheet) cells to the left
- Click the Scale button on the toolbar (the big blue A), and click the plus and minus magnifying glass until you get a scale that you like.
- From here you can select an area on the graph that includes all points, and can create a line of best fit, determine the slope, etc.

For printing:

- File > Printing Options allows you to put your name on it, add comments, etc.
- File > Page Setup allows you to change it to landscape to make it easier to read, but printing it portrait makes it smaller and easier to tape into lab notebooks.
- The printed page includes both the table and the graph, unless you specifically select “Print Data Table” or “Print Graph.”