# Lab 5: Measurements and Uncertainty

## The goal of this lab is to practice making estimates of uncertainty, propagating that uncertainty, and interpreting the results. Be sure to read the assigned sections on the Error and Uncertainty packet, available in Files/Lab Materials before lab. We will practice these techniques by using a simple of a ball dropping to make an experimental estimate of the strength of the gravitational field g.

## Live (Synchronous) Lab

#### Video Analysis and Initial Uncertainty Estimates

Open [Vernier Video Analysis](https://videoanalysis.app/?key=4020e622e6bf436db560eca482f462fb-86ac98513bde5c09cf97fbdc4193ace1-0aa757b14dd396b9d5335332eac63844-d665c75f31e7d685fb4718404e004ev2) and load the “Ball Drop” video from the sample videos. Set the scale in the program using the yellow meter stick visible on the first floor of the building. Set your origin at the bottom-left of the screen.

1. Track the top of the ball at two points ONLY: A, the point where the ball is released, and B, the point where the ball touches the ground. The data table will display the y-positions and times of these two points: copy this data table to your GradeScope document.
2. Referring to the “Estimating Uncertainty” section on pages i-3 and i-4 of the Error and Uncertainty packet, agree with your group on absolute uncertainty estimates for the following values in the data table:

* , the y-position when the ball was released
* , the y-position when the ball strikes the ground
* , the time the ball was released
* , the time the ball strikes the ground

In your GradeScope document, state the uncertainties you estimated for each of the above data points, and explain your reasoning for each uncertainty estimate. There is no one right answer here: the idea is to arrive at reasonable estimates of the uncertainty, and reasonable reasons to support those estimates.

#### Uncertainty Propagation

Kinematics tells us that if a ball is released from rest at time near the surface of the Earth and it falls without air resistance, its displacement at time will be given by

Rearranging gives

1. Use your experimental values for the positions and times to calculate an experimental value for .

Calculating the experimental acceleration is easy. But what about the uncertainty in the acceleration? To get this we need to do propagation of uncertainty: the process of seeing what happens to uncertainty when you do calculations on your data, as you have above. The Error and Uncertainty packet discusses a number of techniques for doing this (and indeed there are whole books about this), but for today’s lab we will use the three basic rules described on page i-5 in the packet. (Note that as applied here, these rules will be extremely conservative, meaning that they will tend to overestimate our uncertainties[[1]](#footnote-1). That is always better than the alternative!)

1. Identify the appropriate “basic rule” to find the uncertainty in the quantity . State the uncertainty and show how you got in in your GradeScope document. Also find the relative (percent) uncertainty in . (Relative uncertainty is described on page i-4 in the Error and Uncertainty packet.
2. Identify the appropriate “basic rule” to find the uncertainty in the quantity . State the uncertainty and show how you got in in your GradeScope document. Also find the relative (percent) uncertainty in .
3. Identify the appropriate “basic rule” to find the relative uncertainty in the quantity . State the uncertainty and show how you got in in your GradeScope document.
4. Identify the appropriate “basic rule” to find the relative uncertainty in the quantity . Finally, convert that value back to an absolute uncertainty. State the uncertainty and show how you got in in your GradeScope document.

#### Interpreting the Result

1. Use your uncertainty value to calculate minimum and maximum values for the experimental value of g. Observe whether the accepted value ( falls within that range, and state clearly whether your experimental result does or does not agree with the theoretical value.
2. Discuss your result:

* If your result agrees with the theory, discuss how uncertainty in the experiment might be reduced to provide a more rigorous test of the theory. That is, propose improved experimental methods.
* If your result does not agree with the theory, discuss why the theoretical model might be an incorrect model of the situation. (That is, discuss how the simple model that may me incorrect when applied to this situation). Note that it important here to discuss potential problems with the theory- this is not the place to revisit uncertainty estimates: if you have done a good job making your initial uncertainty estimates, you should trust them- it is bad science to revise your uncertainty estimates after comparing them to theory!

1. The basic rules overestimate uncertainty here for several reasons. For one thing, errors are likely correlated, meaning that if, for example, one position is “too high”, the other one may be “too high” as well, so that when the positions are subtracted, the error will cancel out. Relatedly, it is fairly unlikely the errors will be in opposite directions, (i.e. one position too high and the other too low), so adding the uncertainties as in the first simple rule is really a “worst-case scenario”. More sophisticated methods of propagation uncertainty, such as adding uncertainties in quadrature, will yield more realistic results, but are beyond the scope of this course. [↑](#footnote-ref-1)