Here in Boulder, the value of the acceleration of gravity is \( g = 9.796 \text{ m/s}^2 \). In this lab, you will measure the acceleration of gravity \( g \) by two completely different methods. In the first method, you will determine \( g \) by measuring the period \( T \) of a simple pendulum. A simple pendulum consists of a mass at the end of a (nearly) massless string. The period \( T \) of such a pendulum of length \( L \) is given approximately by:

\[
T = 2\pi \sqrt{\frac{L}{g}}
\]

Notice that \( T \) does not depend on the mass of the pendulum. This expression for \( T \) is only accurate if the amplitude of the swing is small. For big swings, \( T \) is slightly larger than given by Eqn (1), so we will keep the amplitude to less than 5 degrees.

In the second method, you will measure the time \( t \) for objects to fall a distance \( d \) and determine \( g \) from

\[
d = \frac{1}{2} gt^2
\]

Part 1. Measuring \( g \) with a pendulum.

The length \( L \) of a pendulum is the distance from the support at the top to the CENTER of the mass at the bottom. Adjust the length \( L \) of your pendulum to be close to 1.00 m and measure it as precisely as you can with a meter stick. (Think about how best to measure the distance to the center of the mass.) Describe your procedure for measuring \( L \) in your lab book. Both you and your partner(s) should measure \( L \) independently and then compare answers to estimate your uncertainty.

Set the pendulum swinging with a small amplitude swings (less than 5° as measured with the supplied protractors - the exact angle is not important). Measure the period \( T \) by using the stopwatch to measure the time for 10 complete swings and then divide by 10. (Be sure to start counting from zero, not one.) If \( L = 1.000 \text{ m} \), you should get a value very close to 2.00 seconds for the period. A deviation of more than a percent or so means that you have done something wrong. Measure \( T \) at least 4 times and have at least 2 different persons make measurements (each person makes 2 measurements) in order to get a good average value for \( T \) and an estimate of the uncertainty of \( T \). Roughly speaking, \( \delta T \) should be large enough so that \( T \pm \delta T \) is large enough to cover the spread in your values of \( T \). From your data, compute \( g \) and indicate the uncertainty with the correct number of significant figures. [Side remark: In cases where the total number of measurements is small (4 or less), then the uncertainty \( \delta T \) is roughly half the spread in values of \( T \). However, if the number of measurements is large (10 or more), a more accurate estimate of the uncertainty is given by \( \delta T = \frac{\text{half the spread}}{\sqrt{N}} \), where \( N \) is the number of measurements.]
number of measurements. Note that, with this equation, the greater the number of measurements, the smaller the value of $\delta T$.]

Now we are going to measure $T$ as a function of $L$ and check that $T \propto \sqrt{L}$, as predicted by Eqn (1). Squaring both sides of Eqn (1) yields

$$T^2 = \frac{4\pi^2}{g} L \quad \text{(3).}$$

This equation has the form $y = m x$, where $y = T^2$, $m = 4\pi^2/g$, and $x = L$. But $y = mx$ is the equation of a straight line with slope $m$ that passes through the origin. So, if equation (2) is true, then a graph of $T^2$ vs. $L$ should be a straight line, passing through the origin, with slope $= 4\pi^2/g$.

Measure the period $T$, by timing 10 swings and dividing by 10, for at least 4 additional lengths $L$ from roughly 0.2 m to 1.3 m. (This time, you need only measure $T$ once for each length. Use the same estimate of $\delta T$ that you used before.) Remember to keep the amplitude of swing small. Be sure to record all your results, including the values and the experimental uncertainties for $T$ and $L$.

Make two plots: one of $T^2$ vs. $L$ and another of $T$ vs. $L$. [$T^2$ vs. $L$ means $T^2$ on the y-axis, $L$ on the x-axis.] Use a whole page for each graph. In your report, comment about which plot is more like a straight line and whether your plots are consistent with Eqns (1) and (3). Measure the slope of the graph of $T^2$ vs. $L$ and compare with the predicted value of $4\pi^2/g$. 

\[
\text{slope } m = \frac{\Delta y}{\Delta x}
\]

$y = m \times$
Part 2: Measuring \( g \) with a falling body.

When an object falls freely under the influence of gravity alone, it falls with a constant acceleration \( g \). You will measure \( g \) by measuring the time \( t \) it takes a steel ball bearing to fall a measured distance \( d \), starting from rest, and then compute \( g \) from Eqn (2):

\[
d = \frac{1}{2} g t^2
\]

The ball bearing is released by an electromagnet. The electromagnet and a photocell are connected to a digital timer. The timer starts when the electromagnet releases the ball bearing and the timer stops when the ball bearing crosses the photogate. The distance \( d \) that the ball falls is the distance from the bottom of the ball as it hangs from the electromagnet to the center of the photogate below.

Use one of the three different setups provided to measure \( d \) and \( t \). Record your procedure for determining \( d \) and its uncertainty. Record the times from several trails to get a good average value of \( t \) and an estimate its uncertainty. Use Eqn (2) to determine the value of \( g \).

Are the two values of \( g \) (from parts 1 and 2) consistent? What is their percent discrepancy?
Physics 2010 Pre-Lab Questions Experiment 2

1. Describe briefly the two methods you will use in this lab to measure g, the acceleration of gravity. For each method, describe what you will measure and how you will use these measured quantities to compute g. To describe how to compute g, you should have two algebraic formulas (one for each method) beginning g = ...

2. What exactly is the length of a simple pendulum? Make a diagram to illustrate your answer. (Hint: In the figure of a pendulum at the start of this lab writeup, where precisely is the lower tip of the arrow associated with length L?)

2. In part I of the lab, you measure T by using a stopwatch to measure the time T for 10 complete swings, and then divide by 10. Why do you suppose we suggest this? Why don't you just measure the time for one complete swing, and be done with it?

4. For the experiment described in part 1 of this lab, list two (or more) different reasons why the value of g you obtain might not exactly yield 9.796 m/s².

Note: "Experimental error" or "human error" are not acceptable answers here, or at any time in your lab writeups! These phrases alone contain no useful or thoughtful information. Here is an example of an acceptable kind of answer: "Difficulty in using a flat ruler to estimate the radius of a spherical pendulum mass, which in turn means the measured value of L may be slightly off… " (Come up with at least two more such answers…)

5. A student carefully measures the period T and length L of a simple pendulum and finds $L = 0.906 \pm 0.002 \text{ m}$ and $T = 1.909 \pm 0.003 \text{ sec}$. What are the largest and smallest values of g consistent with these data? Using these max and min values of g, determine the best value of $g \pm \delta g$. If, instead of computing the max and min values of g, the student counts sig. figs., how would she report her final value of g?

6. Dry Lab.