Experiment 1 ~ the Determination of Gravitational Acceleration

The first lab of the semester has three parts:

- **Introduction to statistics, error and measurement, which can be found on page 5.**
- **The actual experiment: "The Determination of Gravitational Acceleration" where you will learn how to evaluate measured data by averages and standard deviations**
- **A tutorial in how to plot data using Excel, which can be found in the Appendix.**

There are questions on the last page of the Experiment that you will need to answer in your lab report.

You will probably want to refer back to the Introduction to Statistics, Error and Measurement, and the Excel Tutorial, later in the semester, as you work on analyzing and graphing data from more complicated experiments.
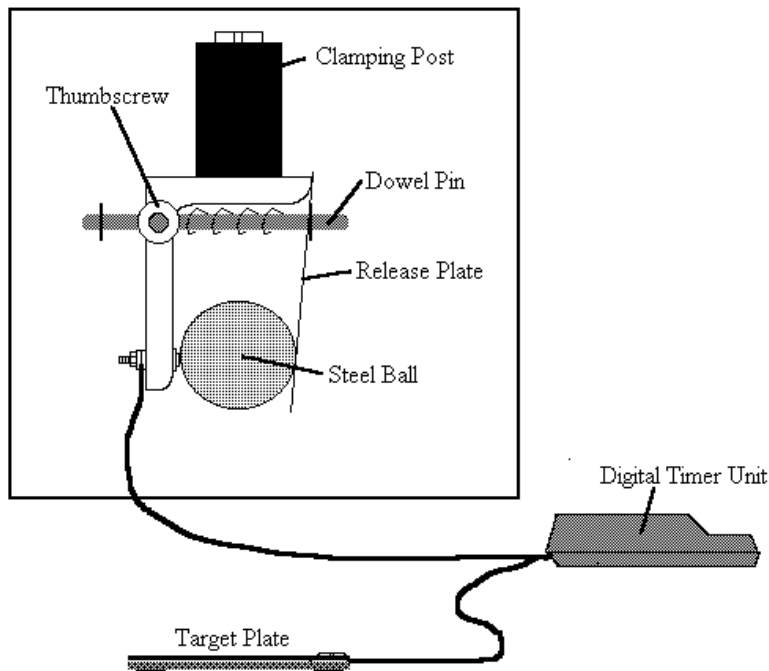
Purpose:

The purpose of this experiment is *to measure the earth's gravitational acceleration from an object in free fall.* You will use the equation of motion of an object in free fall, starting from rest ($v_0=0$):

$y(t) = y_o + v_o t + \frac{1}{2} a\, t^2$

Equipment:

Ball bearing, timer, clamping post, meter stick.

Experiment Part A:

Using the apparatus shown above, drop a ball
- 10 times, from
- 4 different heights (you pick the heights)

To clamp the ball, push in the dowel pin until the ball is tightly clamped, and then tighten the thumbscrew. To release the ball, open the thumbscrew. Be sure to reset the timer to zero before dropping the ball! The lab instructor will show you how to do all this in detail. Be careful when you measure the height: measure _from the bottom of the ball to the pressure pad_.

Collect your data at four different heights and enter the data in the tables below.

For each measured y and t, you can calculate g. Since the initial velocity v_0 is zero, the initial position is h ($y_0 = h$), and the acceleration is $-g$ ($a = -g$), you can rearrange the equation:

$$y(t) = y_o + v_o t + \tfrac{1}{2} a t^2$$

(1) (Equation 1)

to solve for _g_:

$$g = 2h/t^2$$

(2)

You can do this with your calculator, or put the time values into Excel, and make an equation to solve for g at each value of t and y. For each height, calculate the mean value of gravity and time (**<g>, <t>),** and the standard deviation (σ_g σ_t). Again, you can use Excel to do this.

Table 1: Time and Gravity Data

Height 1: h_1=		Height 2: h_2=		Height 3: h_3=		Height 4: h_4=	
t	g	t	g	t	g	t	g
$<t_1>$ =		$<t_2>$ =		$<t_3>$ =		$<t_4>$ =	
σ_t =		σ_t =		σ_t =		σ_t =	
$<g_1>$ =		$<g_2>$ =		$<g_3>$ =		$<g_4>$ =	
σ_g =		σ_g =		σ_g =		σ_g =	

Galileo did this experiment too...
but his experimental setup was the leaning Tower of Pisa...

Analysis Part A:

You now have four mean values of g, each calculated at different height. What is the percent error of each of the values, with respect to the accepted value of g, 9.81 m/s^2?
What is the percent difference between $<g_{highest}>$ and $<g_{lowest}>$

Experiment Part B:

Repeat the experiment above once using the maximum height you can achieve. The height should be over 1.5 meters.

Height 5: h$_5$=	
t	g
$<t_5>$ =	
σ_t =	
$<g_1>$ =	
σ_g =	

Analysis Part B:

You now have five different heights with five different average times. On the next page is an example of a chart with height on the y axis and time on the x axis (h vs. t). Using Excel, try to recreate this plot using your own data. Include a trend line and the polynomial equation (of order 2) for the trend line. In Appendix B you will find some helpful tutorials, if you are not familiar with Excel.

Look carefully at the trend line equation. Excel usually shows 0 as a number near 10^{-14}; so that the equation can be reduced to $y = 1/2ax^2$. What does this value of a represent? (Hint: Compare this equation to equation 1).

Freefall Results: Height vs. Time

$$y = 1/2ax^2 + bx + c$$

Height (meters)

Time (seconds)
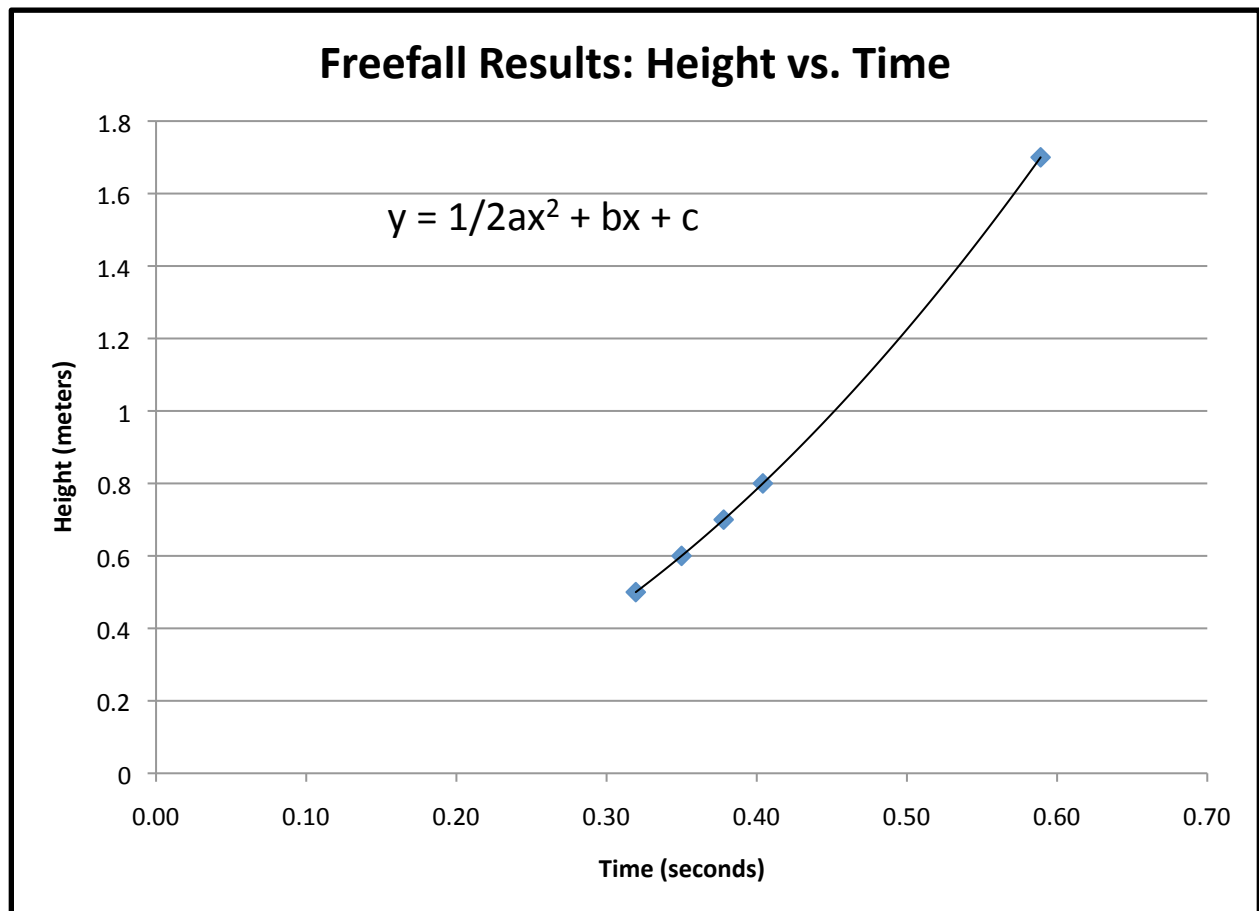
Questions:

1. Discuss the sources of error in the experiment. Were there sources of random error? What were they? What about systematic error?

2. Would you expect the values of g measured at the two different heights to be the same? Why or why not?

3. Suppose you had used a metal ball of a different mass (say, ten times heavier). Would you expect the value of *g* to be the same, or different? Why?

4. For measuring the distance that the ball drops, we suggested that you measure from the bottom of the ball to the pressure pad, in order to get the most accurate distance. Why *shouldn't* you measure from the middle of the ball to the pressure pad? Explain.

5. Which of your values for <g> was more precise? Which was more accurate? Explain.