Name: (Writer) ______________________________ Date__________
(Partners) ______________________________ Section __________

PHYS 231 Lab Exercise: Free Fall

Objective:

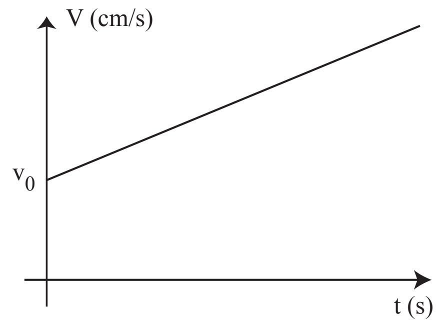
When you release an object from rest and near eye level, how long will it take to reach the ground? The answer must certainly depend on the precise height of release, but on what else?

There are two primary objectives for this lab:

1. To test the conjecture that objects released near the surface of the earth accelerate uniformly downward.
2. To use a series of measurements determine the value for this acceleration, *g* (the gravitational acceleration) to more precisely than possible with a single measurement.

Introduction:

Earth's gravity pulls all objects to the Earth's surface. If gravity is the only *force* acting on the object, the object's motion is called *free fall*. This motion is a motion with the velocity varying in time. Therefore, the distance the object covers is not proportional to the time *t* (as would be the case with motion at constant velocity). Instead, **the velocity <u>change</u> is proportional to time**.



Free fall is an example of *uniformly accelerated motion*. In the case of *free fall,* the acceleration is a constant g = 9.81 m/s^2 (downward). Since the acceleration is constant, by definition, the change in velocity over time is constant and the plot of velocity versus time for free fall motion should be a straight line (as shown).

Since *free fall* is uniformly accelerated motion, the equations of uniformly accelerated motion can be used. As such, we will use the following equations in this lab.:

$$v_{av} = \frac{\Delta x}{t} \qquad (1)$$

where v_{av} = average velocity
Δx = displacement
t = time interval.

$$v_{av} = \frac{(v + v_0)}{2} \qquad (2)$$

where v = final velocity
v_0 = initial velocity.

$$a = \frac{(v - v_0)}{t} \qquad (3)$$

Apparatus Used: Free fall apparatus, spark counter, meter stick, and wax coated paper tape.

Name: (Writer) ___________________________________ Date___________
(Partners) ___________________________________ Section ___________

Procedure: **Part I: Getting the Data**

The instructor will have an apparatus set up to allow each group to measure the position versus time for a freely falling object. To prepare the experiment, make sure that a fresh roll of the waxed tape has been stretched over the entire height of the expected motion.

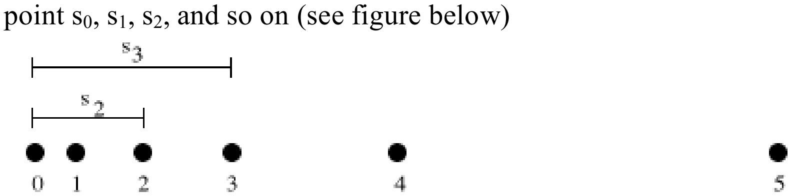
Next, switch on the electromagnet and hold the free-fall mass near the magnet. The strength of the magnet should be sufficient to hold the mass without your further support, but make sure the free-fall mass is centered on the magnet.

Remove your hand and locate the switch to activate the sparking mechanism. The electronics in this experiment will introduce shocks at regular intervals; the shocks will cause tiny burn marks on the wax tape identifying the positions of the object. The device is set to produce shocks at 1/60-second intervals. Hold down the toggle, which initiates the sparks, and then throw the switch to turn off the electromagnet. The mass will begin to fall, and its motion will be recorded on the tape. Data gathering for this lab is as simple as that!

Part II: Determining the Position of the Free-Falling Object

a) Bring the waxed tape to your work area. Stretch it over the table and tape down the ends (this will prevent curling of the wax tape if it is humid).

b) Near the beginning of the motion, there may be several points bunched close together. Pass over those, and go to the first clear dot and label it 0. Notice the mass will already be moving when this dot was made, **so v_0 will NOT be zero**. Draw a little mark by the dots you intend to use. Label them 0, 1, 2, and so on. Consider the distances to each of those points from the starting point s_0, s_1, s_2, and so on (see figure below)



Measure the positions of the marks, s_1, s_2, and so on. Enter these positions *Excel* (you need columns for time and position to start with).

Part III: Plotting Position and Velocity vs. Time

a) Given that the spark timer was set to a frequency of 60 Hertz, it initiates sparks at regular intervals of 1/60 second, you already know the times associated with each of those marks. Enter the elapsed time since s_0 for each mark in the record table.

b) Next, compute the average velocities between the marks using *Excel*. Recall that to compute average velocities you take the distance traveled (between the current and previous "even" mark) divided by the time taken to travel between the "even" marks. This can be written:

$$v_1 = \frac{(s_2 - s_0)}{(t_2 - t_0)}, \qquad v_3 = \frac{(s_4 - s_2)}{(t_4 - t_2)} \quad \text{etc.}$$

Recall: The average velocity during a time interval of uniform acceleration is equal to the instantaneous velocity at the center of the time interval.

c) Using *Excel*, plot a graph of distance traveled versus elapsed time. *Comment on the appearance of this plot here* (is it linear, parabolic, does it increase or decrease, change direction, etc?)

d) Next, use *Excel* to make a separate plot of the average velocity versus elapsed time. Is this fairly linear? If so, compute a slope by fitting a trendline to the data in *Excel*. Record the numerical value and the units.

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In physics, what is the common term we use that corresponds to the slope of velocity versus time?__________

e) Print out a copy of both plots (one for each lab partner), *you will need these for full credit on the lab.*

Part IV: Performing a Statistical Analysis of Average Accelerations

a) Compute an average acceleration between each mark and enter it in your data table. Remember that the average acceleration can be computed using

$$a_1 = \frac{(v_2 - v_0)}{(v_2 - t_0)}, \qquad a_3 = \frac{(v_4 - v_2)}{(t_4 - t_2)} \quad \text{etc.}$$

You are now in position to quote an estimate for the acceleration due to gravity, *g*.

b) Compute the *average* (*mean*) of your average accelerations (you remember how to do this from last week, don't you). Use *Excel* to do this computation easily.

Enter the mean acceleration: _____(include units)

c) How does this acceleration compare with the slope of your *v* versus *t* line? How does this compare with the accepted value for gravitational acceleration at the earth's surface of 9.81 m/s^2?

d) Print out all the data from your lab (one copy for each lab partner), again, *you will need this data (and the previous plots) for full credit.*

Name: (Writer) ____________________________________ Date___________
(Partners) ____________________________________ Section ___________

Discussion: Discuss possible reasons for deviations of your velocity versus time data from the expected straight-line relationship for velocity versus time in the case of *free fall*.

Answer the following questions:

a) How does air resistance affect the measurement of g?
b) Does this experiment prove that the value of g is independent of the mass of the falling object?
c) Notice we didn't ask you compute the standard deviation, σ, for the values of gravitational acceleration. This was because your measurements are not independent of one another (*e.g.* – if the falling weight hits the cable on the way down, several measurements of the average acceleration are affected), the standard deviation of your measurements is not necessarily a good measure of their uncertainty in this case. **How could you get around this problem and determine the uncertainty of your measured value for g?**