PHSX 101L **Experiment 4** **Name:**______________________

Title: Acceleration of a Freely-Falling Body

Object: To study the motion of a freely-falling body including to measure its acceleration.

Introduction: The law of falling bodies says that all objects in free fall (motion under the influence of gravity only) have the same acceleration; near the surface of the earth, it has a value of a_g (often simply called g).

Recently developed techniques in measurement have resulted in very precise experimental results on the value of a_g. At the National Bureau of Standards Labs in Maryland, free fall acceleration has been determined to be $a_g = 9.810424$ m/s^2, while at CSIRO National Laboratory in Sydney, Australia, a_g has been measured as $a_g = 9.7967134$ m/s^2. The high precision of these measurements is indicated by the large number of significant figures reported. Such accuracy is not always possible, mostly because of difficulties in measuring short fall times. For many years the most reliable measurements were made on slowly accelerating systems, from which a_g could be calculated; an example is the pulley system on display at the Smithsonian Institute. The difference in the above values of a_g is due to the fact that the value actually varies from point to point on the earth's surface. One formula, which takes into account latitude and altitude, predicts that a_g in Ephraim should be $a_g = 9.7959$ m/s^2 [CRC, 56th ed. p. F87].

Your experiment today uses a fast timing mechanism to observe a metal cylinder as it falls freely under the pull of gravity (air resistance is negligible). A high voltage between two vertical wires causes a spark to jump between the wires every 1/30 second. The spark passes through the falling cylinder and then through the special paper tape, making a small dot on the tape, thus marking the position of the falling cylinder at each 1/30 second. The rate at which the spark is produced is controlled by the 60 hertz (or 60 cycles per second) power line, which is a very stable timing source.

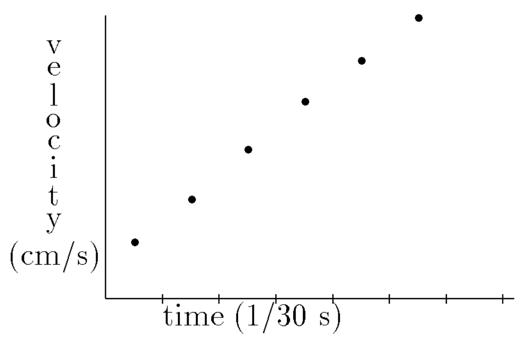
Apparatus: Draw a diagram of the apparatus.

Procedure:

1. Level the apparatus. Verify levelness by dropping the cylinder in a dry run with no sparks.
2. Start the sparker, release the cylinder, and then release the sparker button after the cylinder has landed, all in quick succession.

Analysis:

1. Call the first *good* dot time zero and location zero (you may not want to use the very first dot). Then record in table 1 the displacements for the rest of the dots relative to *that* dot.
2. Subtract successive displacements in pairs to obtain the information for the $\Delta \boldsymbol{d}$ column in table 1. Verify the $\Delta \boldsymbol{d}$ by measuring between successive dots with a ruler. Then divide each $\Delta \boldsymbol{d}$ by Δt (which is 1/30 s) to obtain the average velocity for each time interval (*i.e.*, between successive dots).
3. Subtract successive velocities in pairs to obtain the information for the $\Delta \boldsymbol{v}$ column in table 1. Then divide each $\Delta \boldsymbol{v}$ by Δt to obtain the acceleration for each interval (*i.e.*, between successive velocities). Compute the average of all of the numbers in the acceleration column and record it just below table 1. (Don't forget units.)
4. Make a graph of velocity versus time. The value on the vertical axis for each data point is the average velocity (acquired from table 1) during that time interval. The value on the horizontal axis is halfway between the tic marks representing the times 1/30 s apart. See example below.



5. Draw a best-fit straight line between the points on the graph and compute its slope and read the intercept off the v axis. Think of $v = v_0 + at$ in terms of $y = mx + b$; the slope of your line will be a and the intercept will be v_0.
6. What do you expect a graph of displacement versus time to look like? _______________ Make a graph of displacement vs. time using the first two columns of table 1 as your data. Draw a best-fit smooth curve through the data points. Is the shape of the curve what you expected?

assumed time (s)	displacement $\boldsymbol{d}$ (from 1st dot) (cm,↓)	$\Delta\boldsymbol{d}$ $\boldsymbol{d}_2 - \boldsymbol{d}_1$ (cm,↓)	$\boldsymbol{v}$ $\Delta\boldsymbol{d}/\Delta t$ (cm/s,↓)	$\Delta\boldsymbol{v}$ $\boldsymbol{v}_2 - \boldsymbol{v}_1$ (cm/s,↓)	$\boldsymbol{a}$ $\Delta\boldsymbol{v}/\Delta t$ (cm/s^2,↓)
0	0.00	xxxxx	xxxxx	xxxxx xxxxx	xxxxx xxxxx
1/30					
2/30					
3/30					
4/30					
5/30					
6/30					
7/30					
8/30					
9/30					
10/30					
11/30					
12/30					
13/30					
14/30					
15/30		xxxxx	xxxxx	xxxxx xxxxx	xxxxx xxxxx

Table 1: ave. $\boldsymbol{a}$ = ___________

7. (a) Did your straight line in step 5 above go through the origin? Why or why not?

   (b) What value of acceleration did you compute from the slope of this line?

8. Compute the percent difference between each of your two measured values of a_g (the slope of the line and the average from table 1) and the value of $a_g = 979.59$ cm/s^2 predicted by the formula for Ephraim.

9. On the graph of displacement vs. time also plot the theoretical curve of $x = v_0 t + \frac{1}{2}at^2$ using values of v_0 and a obtained from step 5 of the analysis. How does this theoretical curve compare with the experimental one?

Questions about Free Fall:

1. If an object were thrown straight up
   (a) would it be in free fall (neglecting air resistance)?
   (b) what would its acceleration be on the way up (both magnitude and direction)?

2. In another experiment a body falling straight down at one instant has a speed of 3.00 m/s.
   (a) Compute its speed 0.50 s later.

   (b) Compute the distance it would fall during this 0.50 s.

Conclusions: