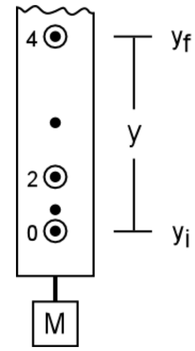
The Motion of Free Fall

Fall 2008



Introduction

In this experiment, you will measure the displacement as a function of time for a mass in free fall, and determine its acceleration and initial velocity.

Experiment

1. Attach a 200-gram mass to a strip of paper tape. Hold the paper tape near the end, and let the mass and tape fall through the timer attached to your lab bench; don't let the tape drag through your hand. This device will create small dots on the tape at $\frac{1}{40}$ -second intervals.
2. Arbitrarily choose a dot near the beginning of the tape (choose the first clear dot you can see). Number this dot *zero*. Circle and number each *even* numbered dot to make it more visible, as shown in the sketch above.
3. Create a data table as follows (the numbering scheme of the "Elapsed time" column is explained below):

Elapsed time, t (dots)	Initial position, y_i (cm)	Final position, y_f (cm)	Displacement, $y = y_f - y_i$ (cm)
0	10.0	10.0	0.0
20		—	—
2		—	—
4		—	—
…		—	—

Note that the dot numbers indicate the elapsed time, where every dot occurs $\frac{1}{40}$ -seconds apart (i.e. 40 dots are created during every second of time). To make our graphing easier, we'll keep time in units of "dots"; later we'll convert time into seconds.

4. In the data table, you will calculate the distance between the zeroth dot and each *even* numbered dot, beginning with the extreme points (shortest and longest distance fallen). In the table above, the longest distance occurs at time t = 20 dots. This calculation gives the displacement, y, of the mass. (*Be careful; you are **not** measuring the distance between each dot!*)

   Important observation: As you collect your data, note carefully the changing separation between each dot on the tape. Since the time interval between each dot is the same, the velocity of the mass must be increasing with time so that more tape is pulled through the timer between dots. Velocity changing with time? Ahh ... *acceleration*!!

5. After you have measured the displacement of the extreme points, begin your experimental graph of **displacement (*y*)** vs. **elapsed time (*t*)** on a sheet of graph paper. Keep the units of *cm* and *dots*. After these two points are plotted, continue to graph points as the displacement is measured.

   Why is the graph created *as* the data points are measured, and not after *all* the points are measured? If you can't answer this question, then you didn't read the "Graphs" section of the *Introduction to Laboratory Practices*! *One point will be deducted from your lab grade for failure to follow the proper graphing procedure.*

Analysis

Initial position, initial velocity and acceleration from: $y = y_o + v_o t + {}^{1}/_{2} a_o t^2$

1. As best you can, *lightly* draw a curve that fits the points on your graph.
2. In Excel, construct a table of your measured elapsed times, *t* (*dots*) and displacement, *y* (*cm*) (in Excel, the quantity plotted along the *x*-axis is entered in the first column!). Plot these points, along with a best-fit curve (a 2nd order polynomial: $y = Ax^2 + Bx + C$); remember to include the equation for the line on the graph. Print your graph when it is finished, remembering to include your name (and your partners) in the header.
3. The coefficients of the polynomial fit, *A*, *B*, and *C*, yield the values ${}^{1}/_{2}a_o$, v_o and y_o from the acceleration equation (be sure you understand *why*!). Record these values in your report, and solve for a_o. Pay particular attention to the units for each coefficient: y_o (cm); v_o (cm/dot); and a_o (cm/dot^2).
4. Convert your values of v_o and a_o to units of cm/sec and to cm/sec^2, respectively (recall that 40 dots = 1 sec).
5. Compare your measured coefficients to their expected values (*i.e. perform a percent difference calculation!*). The *expected* value for a_o should be ***g***, which is approximately 980 *cm/sec*^{2} in Canton. What were you expecting v_o and y_o to be? Record your results for acceleration on the blackboard; keep the units in *cm/sec*^{2}.

Discussion

- Begin your discussion by restating your numerical results (a summary table is a nice way to display these results). In this experiment, you will report your *measured* values for each of the three coefficients (a_o, v_o and y_o) as well as their *expected* values.
- In the Analysis section above, you compared the measured and expected values of the three coefficients. Do you notice a significant discrepancy in one (or more) of the coefficients? Explain the cause of this discrepancy.
- Look at the graph of displacement vs. time you created with Excel. How well does the best-fit line drawn by Excel (the line represents *the theory*) fit your data points (*the experiment*). What can you conclude from this agreement between theory and experiment?
- Examine the results of your classmates. Are the results consistent with each other? Do you notice a trend in these results? If so, what might be the cause of this trend?
- Finally, *carefully* staple the paper tape to the back of the report of one group member – never throw away data!