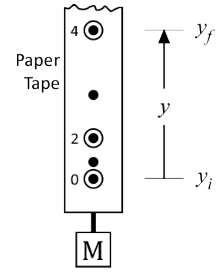
The Motion of Free Fall

Fall 2025



Introduction

In this experiment, you will measure the displacement as a function of time for a mass, M in free fall, and determine its acceleration and initial velocity from the kinematic expression $y = y_o + v_o t + ½a_o t^2$. You will see if your mass falls at a constant rate, and how the acceleration compares to *g*, the expected acceleration.

Experiment

1. Prepare a strip of paper tape to hold the 200-*g* mass: Tear off a length of paper tape that is a little shorter than the height of the timer attached to your lab bench; make a loop at the 'bottom' end of the tape and secure with tape.
2. Feed the 'top' end of the paper tape through the timer, between the carbon disc and metal striker plate, and attach the 200-*g* mass. While holding the paper tape near the 'top', your partner will turn the timer on (move the switch *left* to **40** Hz); you will release the tape when you hear the timer start. *Be sure not to let the tape drag through your hand!* At this setting, the timer will create small dots on the tape at $1/40$ -second intervals.
3. Draw a circle around the first clear dot you can see near the beginning of the tape and number it *zero* (check with your instructor that you have chosen a reasonable dot). Circle and number each *even* numbered dot to make it more visible, as shown in the sketch above.
4. Create a data table in Excel with the headers below. Notes about the data table follow:

t (*dots*)	y_i (*cm*)	y_f (*cm*)	y (*cm*)

- The elapsed time, *t*, is in units of *dots* (the even-numbered dots you circled), where each dot occurs $1/40$ -seconds apart (*i.e.*, 40 dots are created during every second of time). This will make it easier to graph your data; later you will convert time units into seconds.
- The initial position, y_i, is held constant at 10.0 *cm*. You will introduce measurement error if you use the end of the meter stick, since the end may be worn due to its age, or obscured by a protective metal cap. Using this position for y_i gives you a position that allows easy calculation of the displacement. Affix the paper tape to the bench and lay the meter stick next to it with the 10.0 *cm* mark aligned with the dot zero.
- The final position, y_f, is the measured position of each even-numbered (circled) dot. The displacement, *y*, is the distance the mass falls, and is calculated as the difference between the two position measurements: $y = y_f - y_i$.

5. Measure the position of the first three even-numbered dots (including dot zero) and record them in your table (Excel requires *at least three points* to properly create an x-y scatter plot). Calculate the displacement, *y* of the mass for each of these points in the data table. *Remember that you are* ***not*** *measuring the distance between each dot!*
6. Create a graph of *y* vs. *t* in Excel with the three data points measured. Continue to measure the displacement for your remaining even-numbered dots, *remembering to plot each point as it is measured* – refer to section III of *Graphing & Curve Analysis Using Excel* to easily add new data points to your existing graph.

   Important observation: As you collect your data, carefully note 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? Aha... *acceleration*!

Analysis - Calculating the initial position, initial velocity, and acceleration of the falling mass

1. After all your data are plotted, add a best-fit curve (a 2nd order polynomial: $y = Ax^2 + Bx + C$); remember to include the equation for the line on the graph and increase the font size of the equation.
2. Use the procedure introduced in last week's Excel exercise (pg. 3 "Analyzing the Graph" – matching the best-fit function to the theory) to determine the initial position (y_o), initial velocity (v_o), and acceleration (a_o) of the falling mass. *Keep in mind that your graph uses 'dots' for time units, not seconds!*
3. Convert your values of v_o and a_o to units of *cm/sec* and *cm/sec²*, respectively (recall that 40 dots = 1 sec).
4. Record your acceleration results on the blackboard; keep the units in *cm/sec²*.
5. In every experiment we perform, we will compare the calculated results to their expected values. We will do this by calculating the *percent difference* (*%Diff*), which is the difference of the two values divided by their average. So, for two values α and β, the percent difference is calculated as:

$$\%Diff = \frac{Difference}{Average} \times 100 = \frac{(\alpha - \beta)}{\frac{1}{2}(\alpha + \beta)cm}$$

Calculate the *%Diff* between your measured acceleration, a_o, and its expected value, ***g***, approximately 980 *cm/sec²*.

Discussion

- Restate the numerical values of your *calculated* values for each of the three coefficients (a_o, v_o and y_o) as well as their *expected* values. Also restate the *%Diff* between your acceleration values.
  - *Note*: You cannot calculate the percent difference between two numbers if one of those numbers is zero; if you try this calculation, you will always get a 200% difference! If your expected value is zero, then you should expect that your measured value is very small and close to zero – **if** the experiment and theory agree! Be sure to comment on this agreement between your values.
- Be sure that you indicate in your journal which timer you used (in the *Sketch* section).
- Do you notice a *significant* discrepancy between your calculated and expected values of acceleration, initial velocity, and/or initial position? Briefly explain the cause of the discrepancy in each parameter.
- Examine the results that your classmates have written on the blackboard. 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?
  - *Add a new sheet to your journal with a table of the class results to support your conclusion!*