LAB 3
Acceleration Due to Gravity

OBJECTIVES

(1) Practice graphing and interpreting position, velocity and time data.
(2) Measure the acceleration of a freely falling object.
(3) Practice using Excel to fit a curve.

EQUIPMENT

Freefall apparatus, spark timer, meter stick, ruler, and special graph paper.

PROCEDURE

Part 1: Finding the Acceleration Due to Gravity by Hand

(1) Obtain a record of a falling ball's positions at regularly spaced time intervals ($1/60\,\mathrm{s}$) on a spark tape.

(2) Circle the marks and number them sequentially, starting with 0. These labels correspond to $t = 0\ s,\ t = 1/60\ s,\ t = 2/60\ s$, etc.

(3) Measure the position of each of the marks, relative to the "0" mark. Record this data in a neat table in your lab notes.

(4) Draw a full-page graph on the special graph paper (to be handed out) showing the position of the ball as a function of time. Put position "*y*" on the vertical axis, and time "*t*" on the horizontal axis. Note that the points do not lie along a straight line. That is, the ball goes farther in each successive interval. Therefore, the *speed* of the ball (and the *slope* of the graph) is increasing. We conclude that the ball must be *accelerating*.

(5) Determine the speed of the ball at four selected times by measuring the slope of a line tangent to the *y vs. t* curve at each of the four points. Be careful to watch the units — the rise is in centimeters, the run is in seconds, so the speed is in *cm/s*. Put these speed values in a table of data in your lab notes, and draw a separate graph of speed verses time.

- *Do your four speed values lie along a straight line?*
- *If they do, what does this mean about the acceleration of the ball? Explain.*

(6) If you are convinced that the acceleration is constant, draw a single "best fit" straight line through *all* of the data points on your *v vs. t* graph. (Hint: this means not playing connect the dots.) Determine the slope of this line to determine the value of "g," the acceleration of gravity.

(7) Now draw the "steepest best-fit line" and the "shallowest best-fit line" through your data points of *v vs. t*. *Determine the slope of these lines to determine a "confidence interval" for your group's data.*

(8) Put your result on the board and on a Results Sheet at the front of the room so that you can get a class average g_{ave} and a standard deviation σ_g using Excel. Perform the following analysis:

- *Set up a "confidence interval"* $g_{ave} \pm \sigma_g$. *Does* g_{thy} *fall in-between or outside the confidence interval? If it falls in-between, then the accepted value is consistent with the experimental results. If it falls outside, the accepted value is not consistent.*

Part 2: Using Excel to Find the Acceleration Due to Gravity

(1) Open Excel and enter the number 1 in cell A1 and the number 2 in the cell A2.

(2) Highlight cells A1 and A2 and then drag the square at the lower right hand side of cell A2 down. This will fill in cells A3, A4, … with the numbers 3, 4, … You should fill in column A with as many data points as you have from Part 1.

(3) We want to divide each of these number by 60 to have a column of times (1/60 s, 2/60 s, …). You can do this as follows: Click on cell B1 and then type =. This will allow you to create a formula. Enter the formula: A1/60. Cell B1 should now show 0.016667. To fill in the other cells, click on cell B1 and then drag the square at the lower right hand side of cell B1 down.

(4) Fill in column C with the positions (in cm) corresponding to each time.

(5) Highlight all of the data in columns B and C. With the data highlighted, click on the ***Chart Wizard*** button (it looks like a bar chart) and then click on **X-Y (Scatter).** This will create a graph of the data points. You can the customize the graph with a title, axis labels, … (Note: a copy of your graph should be turned in.)

(6) Now that the data has been plotted, you can fit it to a curve (called a trendline in Excel) as follows. Right click on any data point and click **Add Trendline**. Click on **Polynomial** and make sure the order is set to 2. This will fit the data to a curve of the form $y = ax^2 + bx + c$. In order to see what equation Excel fit the data to, click on **Options** and then click on **Display equation on chart**. The data should now be fit to a curve.

(7) To get the acceleration due to gravity, remember that what you have really fit is the position of a dropped object as a function of time. For an object in freefall, the position as a function of time is given by the equation $y = y_0 + v_0 t + \frac{1}{2} a t^2$ where *a* is the acceleration due to gravity. The polynomial $y = Ax^2 + Bx + C$ therefore corresponds to $y = \frac{1}{2} a t^2 + v_0 t + y_0$.

- *Compare your result g_{expt} with the accepted or theoretical value of g_{thy} = 981 cm/s^2 using the percent difference:*

$$\% diff = \frac{\left(g_{\exp} - g_{thy}\right)}{g_{thy}} \times 100\%$$

How do they compare?

(8) If time allows, put your result on the board and on a Results Sheet at the front of the room so that you can get a class average g_{avg} and a standard deviation σ_g using Excel. Perform the following analysis:

- *Set up a "confidence interval" $g_{ave} \pm \sigma_g$. Does g_{thy} fall in-between or outside the confidence interval? If it falls in-between, then the accepted value is consistent with the experimental results. If it falls outside, the accepted value is not consistent.*