PHY251 Fall 2008 Practical Exam 1
Acceleration of a freely falling body

Objectives:

- to investigate whether the velocity of a freely-falling body increases linearly with time
- to calculate an acceleration of a freely falling body from a set of data points

Apparatus: In this experiment you will be given the position of a freely falling body collected by an unmanned spacecraft on Planet X. From the data, you will determine the acceleration due to gravity on the planet's surface. The data strip you will use will be on the lab handout given to you when you take the practical exam. The time interval between two adjacent sparks, τ, will also be on the handout you will receive when you take the practical exam. A total of 8 data points will be on your data strip.

Theory: Measuring the distances between any two marks, Δy, and knowing the times between the corresponding sparks, Δt, it is possible to calculate the <u>average</u> velocity during this interval using the formula

$$v = \frac{\Delta y}{\Delta t} \qquad (1)$$

If Δt is small enough, we can assume that the velocity at any instant within this interval is approximately equal to this average velocity. In the case where acceleration is <u>constant</u>, the instantaneous velocity at the middle of the time interval Δt is exactly equally to the average velocity of the object during the time interval Δt.

In general, for the motion of a body with a <u>constant</u> acceleration a, the velocity v is given by the equation

$$v = at + v_0 \qquad (2)$$

where v_0 is the velocity of the body at t = 0. Since in our case the body is falling freely,

$$a = -g, \qquad (3)$$

where g is the magnitude of the acceleration due to gravity on the planet's surface. The negative sign in front of g is to indicate that the direction of the acceleration is in the negative direction (i.e. downward). Therefore it follows from (2) that for a freely-falling body

$$v = v_0 - gt \qquad (4)$$

Thus g can be determined from a plot of v vs. t since the slope of any velocity versus time graph is just the acceleration. The obtained value of g can then be compared with the known value of the acceleration due to gravity.

Procedure: The quantities needed to analyze the motion are the position (y), velocity (v) and time (t) of the points on your data strip.

The points on your tape will be pre-labeled, 1 through 8. The position of point 8 is $y_8 = 0.0$ cm and the time the body was at point 1, $t_1 = 0.0$ seconds will also be pre-labeled..

Next, put a ruler on your tape such that height y=0.0 cm corresponds to point #8 and that height INCREASES as you move towards point #1. Measure the position of each point with this ruler and write the y position next to each of the points. Each point MUST be labeled with its total distance from y = 0.0 cm NOT its distance from the previous point.

After completing this, transfer the y positions into the spreadsheet. Assign a reasonable value for the uncertainty in your position measurements (δy) and have Excel calculate the uncertainty in the displacement ($\delta\Delta y$). Also, have Excel calculate the displacement (Δy), the velocity (V_y) and the uncertainty in the velocity (δV_y) for all points during the fall except for the first and last points. As discussed in the theory section, the instantaneous velocity at time t_i are found by finding the average velocity during the time interval of t_{i-1} to t_{i+1} for each of your points, $v = \frac{\Delta y}{\Delta t}$. In this equation Δy is the difference between the position of the spark FOLLOWING and the position of the spark PRECEEDING the spark for which you are trying to calculate a velocity. Similarly, Δt is the time interval between the FOLLOWING spark and the PRECEEDING spark. For example, the instantaneous velocity at $y = y_2$ is $v_2 = \frac{y_3 - y_1}{t_3 - t_1}$.

Transfer your data columns into Kaleidagraph and prepare a graph of V_y vs. time with error bars and fitted with a best-fit line. Make sure the equation of the best-fit line is on your graph along with the uncertainties in the slope and intercept.

Questions

1. From your graph, what is the acceleration due to gravity on the surface of Planet X (don't forget the uncertainty)?
2. Is the value you measured for the acceleration consistent with the theoretical value (you will be given the theoretical value during the exam)? Explain.
3. What is the initial velocity (v_0) of the body?
4. Does the magnitude of the velocity increase linearly with time? Explain.

Checklist

Your lab report should include the following four items:

1) your spreadsheet
2) The formula view of the spreadsheet
3) The graph with liner fit and error bars for V_y
4) Answers to questions

The formulae, definitions and errors from pages 24 and 25 of your lab manual will be provided for you in the exam, as will a copy of this handout. No calculators, notes or other aids may be used.