EXPERIMENT: ANALYSIS OF A FREELY FALLING BODY

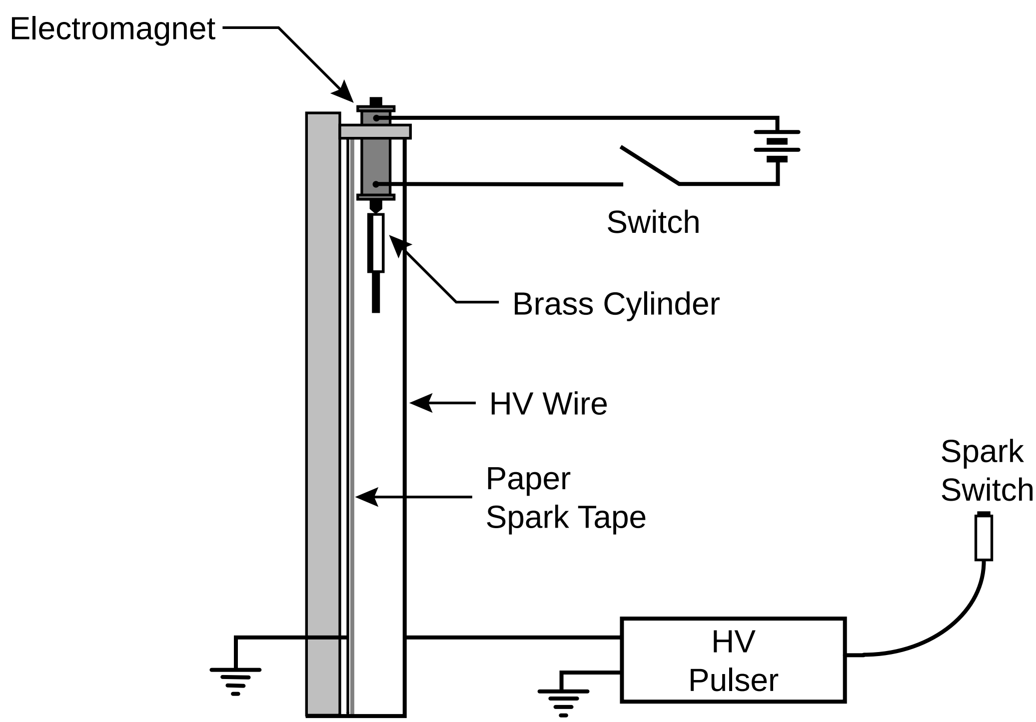
Part I: dependence of speed and position on time.

Primary OBJECTIVE: Investigate whether the velocity of the falling body increases linearly with time and calculate a value for *g*, the acceleration due to gravity. Verify how the distance varies as a function of time

APPARATUS:

Behr Freefall System, Spark Timing System

BEHR FREE FALL SYSTEM



THEORY

In this experiment, a brass cylinder is dropped and a record of its fall is made. Before the measurement, the cylinder is suspended at the top of the stand with the help of an electromagnet. When the electromagnet is turned off, the cylinder starts to fall. Simultaneously, the spark timer starts to send short high-voltage pulses on two wires, stretched along the cylinder's path.

At the time of each pulse a spark goes through the wires and the cylinder, leaving a mark on the special paper tape. The time interval between two adjacent sparks τ is 1/60 of a second.

Measuring the distances between any two marks Δy and knowing the times between the corresponding sparks Δt, it is possible to calculate the average velocity of the cylinder in this interval, using the formula

$$v = \frac{\Delta y}{\Delta t}. \tag{1}$$

If Δt is small enough, we can assume that the velocity at any instant within this interval is approximately equal to this average velocity.

For the motion of the body with the constant acceleration a, the velocity v is given by

$$v = at + v_o, \tag{2}$$

where v_o is the velocity of the cylinder at $t = 0$. Since the brass cylinder is falling freely,

$$a = -g, \tag{3}$$

where g=9.81 m/sec^2 is the magnitude of the gravity acceleration, it follows from (2) that

$$v = v_0 - gt \tag{4}$$

Thus g can be determined from a plot of v vs. t, and compared with the known value. The position of the cylinder, denoted by y, as a function of time, is given by the standard equation for an object which is undergoing constant acceleration. If it starts to fall from an initial height y_o with an initial velocity v_o, then this equation looks like

$$y = y_0 + v_0 t - \tfrac{1}{2} g t^2 \tag{5}$$

PROCEDURE

Using the free fall apparatus, drop the brass cylinder and record on spark tape the location of the falling cylinder after a series of equally spaced time intervals, $\tau = 1/60$ sec.

The quantities needed to analyze the motion are the position (y), velocity (v) and time (t) of the points on your spark tape. The choices of time, $t = 0$ and height $y = 0$ are arbitrary and do not necessarily refer to your first or last data points. However, as your object falls the position y must decrease (becoming negative if necessary).

After you have performed the experiment, tape the paper strip to your lab table. Label the points on your tape, starting with the last point as #31 and label them in descending order. Make sure that point #31 is the last data point and not the point where the brass cylinder is stuck in the putty and simply sparking. Point #1 will not necessarily correspond to the very first point, but the very first points are somewhat ambiguous anyway. Put a ruler on your tape such that y=0.0 cm corresponds to point #31 and y increases as you move towards point #1. Measure the locations of each marker with this ruler and write the y position on the tape next to each marker.

After completing this, transfer the y positions into the spreadsheet. Calculate the velocity at all points, except the first and the last, during the fall using the spreadsheet. Be sure you do at least one sample calculation The instantaneous velocities at these points are approximated by finding the average velocity at each of your measurements $v = \frac{\Delta y}{\Delta t}$, where Δy is the distance between the preceding spark and the following spark and Δt is the time interval between these sparks. More details are given in the Appendix "Formulas, definitions and errors for the Free Fall experiment".

Transfer the columns of time, *y* positions and velocities from your spreadsheet to Kaleidagraph for graphing.

Prepare the following graphs:

I -- a graph showing *v* vs. *t* with the slope and intercept clearly indicated and calculated. From the slope, determine the gravitational acceleration -g- in cm/sec^2.

II-- a graph showing the y position versus time.

Questions to be answered:

1) When finding the velocities why should you use sparks on either side of the point at which you are calculating the speed by $v = \frac{\Delta y}{\Delta t}$?
2) What is the intercept (value of velocity at t=0 sec) determined from graph I and what does it mean?
3) From graph I find the time at which v= 0 cm/sec.
4) Determine the slope from graph I and from that the gravitational acceleration -g- in cm/sec^2.
5) What equation describes graph II ?
6) When the initial velocity is zero, what would you plot to make graph II linear: y^2 vs. t or y^2 vs. t^2 or y vs. t^2 ?

CHECKLIST:

Your lab report should include the following:

1) A spreadsheet with point numbers and Δy's recorded + sample calculations.
2) Plot of the height vs. time
3) Plot of velocity vs. time with slope (in cm/sec^2)
4) Interpretation of the two plots
5) Answers to questions
6) One member of each group should turn in a spark tape record of the freefall
7) Since You will use the obtained results in the next lab, save the spreadsheet in the folder "Results/Your section". Do not forget to take the manual for the next lab!

Formulas, definitions and errors for the Free Fall Experiment

Definitions:

In this experiment you measure the position of a falling mass -*m*- at fixed time intervals. The fixed time interval is determined by a high voltage spark source. Read off the time between sparks (-τ-) from the setting on the spark source.
You will measure the positions at each spark as y_1, y_2, y_3, y_4, etc. in centimeters [cm]. These positions will be referred to as y_i.
To measure the speed at point -i- (for example i=6) you determine:

$$\Delta y_i = y_{i+1} - y_{i-1} \text{ in our particular example: } \Delta y_6 = y_7 - y_5$$

from your measurements. On your data sheet this is labeled as Δy(i). The speed at point -i- is now determined by dividing the distance Δy_i (=Δy(i)) by the time elapsed between the two points: 2τ. So the speed V_{y_i} is given by:

$$V_{y_i} = \frac{\Delta y_i}{\Delta t} = \frac{\Delta y_i}{2\tau} \text{ [cm/sec]}$$

The errors for these quantities are defined as follows:

For each measured y_i you assign an error based on how accurate you can measure that point. This error is called δy. This error determines all other errors in this lab. For the following formulas it is assumed that the error in -τ- and -*m*- are zero. Here are the definitions:
The error in Δy at each point -i- is the same and is given by $\delta(\Delta y) = 2\delta y$
The error in the speed at each point -i- is:

$$\delta(V_y) = V_y \frac{\delta(\Delta y)}{\Delta y} = V_y \frac{2\delta y}{\Delta y} = \frac{V_y}{\Delta y} 2\delta y = \frac{2\delta y}{2\tau} = \frac{\delta y}{\tau}$$