IB Moving Plots

Here you will use a 60Hz tape timer to make position and velocity v time graphs of an object in free fall. (or nearly in free fall)
If you need help with this there is a website for this lab with videos

Getting a Tape:

1. **You and one partner** will need a mass, a spark timer kit and some masking tape. You may work in a group larger than two to gather data, just get a different tape for every two people at least.
2. Cut a 1.3 m length of expensive silver timer tape, and feed it from the top through the tape timer, so that about 5 cm or so sticks through the bottom. Have one person stand up on a chair holding the tape near the other end (way up high), and have the other person clip the 0.5 kg mass to the other end. (If it slides off, try putting a bit of masking tape on the timer tape on that end) Pull the mass up as high as you can, turn the timer on, wait until the mass stops swinging, and have the person on the chair release the mass so it falls into the sandbox on the floor.

Analyzing the Tape:

1. Tape a meter stick to the table, and tape your timer tape next to it at both ends so the first clear dot is at the 0 cm end of the meter stick.
2. Write down, measuring to the nearest millimeter, where the dots fall on the meter stick. These numbers should increase from 0 to almost 100. Do not measure between the dots.
3. In Google Sheets, make a column that is labeled Time (s), and have it be every 60th of a second. (0, 0.01666, 0.03333, 0.05000, 0.06666, etc.) There is a quick way to do this that I will show in the video. In the second column labeled Position (cm) type in your positions of your dots, starting with the first dot at 0 cm, and ending with a number close to 100 cm. In your third column labeled Velocity (cm/s), make a formula that is the distance traveled in the last 1/60th of a second, divided by the elapsed time (1/60th s) This will look like "=(B3-B2)*60". You will have one fewer of these than positions, and this will start next to the second position.
4. Make **two** nice **x-y scatter** graphs: (Vertical vs. Horizontal)
   a. Distance (cm) vs time (s) – choose the smooth line graph, label the axes etc., and make it a separate sheet. Add a second order polynomial trendline, and label it with the equation.
   b. Velocity (cm/s) vs. time (s) – choose the points only, and you could put this graph on the same page as the data to save paper. Add a "Linear" trend line to this graph, displaying the equation on the graph.

Write up:

Tangent Lines: Pick a smooth part of the distance vs. time graph. •Draw a long tangent line with a ruler to a smooth part of the curve. The line should go off the plot frame at both ends. •By using the coordinates read from your axes of where your tangent line enters and exits the plot frame, find the slope of the line you drew. Show this calculation on the graph itself. •Your tangent line is tangent at a certain point in time. Read this from the time axis of your graph. How does that slope compare the velocity at that time you calculated in the data table? (Compare the slope of the tangent line to the velocity at that time read from the values you calculated in step 4 above – the velocity column.)

Do this for two points on the graph. Each person should do their very own unique tangent line.

(Over) Analysis of the data: We will find the acceleration of the mass four different ways, as well as determine what the exponent is:

A. Polynomial model on position graph: A spreadsheet will show your equation in the form $y = Ax^2 + Bx + C$. Our formula is $s = ut + {}^1\!/_2at^2$ where $u = 0$, so from the Excel polynomial, C and B should be 0 or thereabouts (don't worry if they are not) but most importantly, A (The coefficient of x^2) will be ${}^1\!/_2a$ - half the acceleration of the mass. So double A, (the coefficient of x^2) and you have the acceleration from this model. **State the value for acceleration obtained this way.**

B. Slope of velocity graph: This one is easy – the slope of the velocity vs. time graph **is** the acceleration. **State the value for acceleration obtained this way.**

C. Log-Log: Make a new sheet and paste the time and position data in there. Create two new columns – one of the natural log of time "Ln(time)" and one that is the natural log of distance "Ln(distance)". Make a graph of Ln(distance) vs Ln(time) and put a linear model through it and display the equation on the chart. Since we think the position is going to be a power function distance = ${}^1\!/_2at^2$, then Ln(distance) = Ln(${}^1\!/_2$a) + 2Ln(time) so we will get a graph that has a slope of 2 (or we should) and a y intercept of Ln(${}^1\!/_2$a). **Use the log log graph to determine the exponent, and also the value for acceleration (From the y-intercept, right?)**.

D. Linearization: At this point we think the exponent for the power function of distance is 2, but we really want to make IB happy, so let's linearize the data. Since we think that position = ${}^1\!/_2at^2$, if we graph position vs t^2, we ought to get a straight line with a slope of ${}^1\!/_2$a. Make a new sheet, paste the distance and time data in it, and insert a column after time that is the time squared. Graph position vs. time squared. Stick a best fit line through it and display the equation. **State the value of the acceleration from the equation of the line.**

•Write a sentence where you state what the acceleration is using all four ways (From A, B, C and D) of calculation, and compare them. Are they close?