As derived in class, all atomic nuclei undergo decay in a manner consistent with the following mathematical relationship:

$$N = N_0 e^{-kt}$$

Where

N_0 = the number of nuclei in the sample at time t = 0
N = the number of nuclei present in the sample at time t
t = time
k = the nuclear decay constant

Using the "nuclear decay cubes" (wooden cubes with only a single face painted green), you will produce a table of data that represents number of nuclei that decay during each successive time interval. This will be done by rolling the cubes and removing the cubes that come up "green" after each roll. For simplicity, you will assume that the time between rolls is 1.0 min. This data will be tabulated and posted on the Advanced Physics website (XL#05-Nuclear Decay data)

Using the results of your individual experiment:

a. N VS. T – PLOT AND TRENDLINE: Calculate and plot N (the actual number of nuclei present in the sample) vs. t and use "TRENDLINE" to find the number of nuclei present in the original sample (N_0) and the nuclear decay constant (k). (What TRENDLINE option is appropriate for plotting the given data?). Be sure to include the equation and the R^2 value on the plot. [Please refer to the ***Reference and Style Guide for Microsoft Excel*** for help with this spreadsheet function.]

b. LINEARIZING N VS. T DATA– PLOT AND TRENDLINE: Take the natural log (ln) of the mathematical function and algebraically simplify the expression until it is "linear." Plot the appropriate data such that you can use the linear option in TRENDLINE in order to find the *theoretical* number of nuclei present in the original sample (designated as N_0*) and the nuclear decay constant (k).

c. USING LINEST TO IMPORT MATHEMATICAL MODEL VALUES AND STATISTICAL INFORMATION: Use the "LINEST" function on the spreadsheet to calculate the *theoretical* number of nuclei present in the original sample (N_0*), the nuclear decay constant (k) and relevant statistical information (R^2 value, standard errors in slope and intercept). [Please refer to the ***Reference and Style Guide for Microsoft Excel*** for help with this spreadsheet function.]

d. USING LINEST RESULTS TO PRODUCE AND PLOT OTHER "TRENDLINE" MODELS: Using your *experimental* data, calculate and plot (on the original N vs. t plot) the *actual* number of nuclei that have decayed as a function of time. Then, using the *model* values from LINEST, derive a mathematical model for the *theoretical* number of nuclei that have decayed as a function of time. Add these results to your original N vs t plot. [Plot the *actual* number decayed as data points and the *theoretical* number decayed as a smooth curve (no points).]

Repeat this process using the average values for the all of the experimental trials supplied by your instructor (see spreadsheet "APhys-XL#5-NuclDecay-data.xls")

Purpose+Procedure — Mathematical Methods and Physical Models

In an embedded Word document (or series of embedded Word documents) *on a separate worksheet*, you are expected to include a thorough, step-by-step discussion/description of the physics (or mathematics), including a clear statement of how (and why) you derived/calculated all values. Clear, well-labeled diagrams should be included as part of that discussion. This is your opportunity to demonstrate your depth of insight and understanding and to discuss what you learned by completing this exercise. You should use the drawing tools in Microsoft Word or Excel to produce annotated diagrams.

Analysis of Results + Questions, Answers and Annotations

As a part of your analysis, you should:

(i) Compare and contrast your results for your individual trial with the results using all of the experimental trials. In particular, discuss the differences in the R^2 value and the standard error in the value for the rate constant in each case. What is the R^2 value designed to tell you? What is the standard error (representative of the ± uncertainty in the computed value) as a % of the computed value? How does this ±%uncertainty change when comparing a single data set to the average of all of the trials? What does this reveal about the nature of *random errors*? In addition, comment on how these conclusions are reflected in the "appearance" of the plots — how well do the trendlines fit the data in each case? Account for why particular trendlines that you produced may not accurately reflect trends in the data.

(ii) Note the value for the rate constant (for both the individual trial and the overall results). Recall that, for first order kinetics, $dN/dt = -kN$. Given how the "decay cubes" are constructed, what would you expect the value for "k" to be? Explain. Be sure to compute the experimental error and % error in each case. Include these computations on your spreadsheet.

As with the procedure, this analysis should be on a separate worksheet ***as an embedded Word document.***

In addition to the questions below, *be sure to address other general questions* as posed in the document ***APhys-XL Labs–Format-0809.pdf***

1. What is the significance of the time when the N vs. t and the $N_0{*}– N_0{*}e^{-kt}$ vs. t plots intersect? Explain. Perform a calculation on your spreadsheet that confirms/supports this conclusion.
2. From the TRENDLINE result, graphically estimate the number of nuclei that are present after approximately 8.5 minutes? What fraction of the original number of nuclei remain at this point? How does this compare to the number present at the intersection of the two plots? Why is this significant?

REMEMBER: All XL labs have "required elements" of content and style. Be sure to refer to the ***Grading Rubric for Advanced Physics XL Labs***, ***APhys-XL Labs–Format-0809.pdf*** and the ***Reference and Style Guide for Microsoft Excel*** in order to acquaint yourself fully with these requirements.