Lab E1: Statistics of Radioactive Decay

3/22/03

Goals: 1) To learn about the statistical nature of radioactive decay
2) to learn how to calculate standard deviation and the standard deviation of the mean
3) to learn how to report the best value of a measured quantity and its uncertainty
4) to learn ways to reduce the uncertainty in the best value of a measured quantity

Prelab: 1) Format your lab book in advance by preparing the two data tables described in **Collection and Analysis of Data** (Part 1, Step 4 below). Be sure to leave room for answering questions.
2) Know how to calculate a standard deviation on the calculator you bring to lab (read the calculator handbook!)
3) Know how a Geiger Counter works (called a “radiation monitor” below); see web reading

***** You <u>MUST</u> have your own calculator (TI-83, 83plus, 89) -- and know how to find the standard deviation -- in order to enter the lab area! *****

Equipment and Cautions:

- In this lab, you'll be using a Radiation Monitor and LabPro interface attached to a computer. This allows the computer to count radioactive emissions that are detected in a Geiger-Mueller tube inside the Radiation Monitor. **<u>In using the Radiation Monitor, be careful not to touch or bring anything close to the thin window on the top of the Monitor (this will be the bottom of your upside-down Monitor).</u>** This window is very delicate. If broken, the tube will not function. The metal screen in front of the window will protect it somewhat, but beware of thin, pointed objects that could pierce the screen; also, never leave the Radiation Monitor with the screen side facing upward, since foreign objects could fall behind the screen and damage the equipment.

- The radioactive sources that you will be using are not active enough to be harmful. The beta (electron-emitting) and gamma (-ray emitting) sources are completely enclosed in plastic disks so that there is no danger of contacting or ingesting the radioactive materials. If you want to know what nucleus is actually decaying, you can look for the element symbol labeled on the face of the green, orange, or blue disk. **<u>Whenever you finish with a radioactive source, place it back in the labelled box of sources.</u>**

1. ***To get started*.....**plug the jack of the Radiation Monitor into the DIG/SONIC 1 port of the LabPro interface box. Notice the two switches on the Monitor. Set one of them to "x1"; set the other one to ON (or to AUDIO). Place a beta (or gamma) source near the Geiger tube (i.e. near the metal screen). You should notice that a red light on the Radiation Monitor is flashing. If you set the switch to AUDIO, you should hear clicks coming from the monitor. The needle on the Monitor should move to the right. The clicks and/or fluctuating needle indicate that the tube is detecting radioactive emissions. In order to get the computer to count and time these emissions,

- Select Start, Programs, Vernier Software, Logger Pro 2.0. If you get a scan message, click Scan, then OK.
- Then go to Files, Open and navigate to the Probes and Sensors, then Radiation Monitor directories. Open the file Histogram.
- Four windows should appear on the computer screen: a graph of Radiation vs. Time, a histogram of Radiation vs. Bin, a Radiation-Live Meter box, and a Histogram Table.
- Close the Histogram Table and Meter Window by closing the windows with the ‘x’ button in their upper right hand corner, and minimize the Graph Window with the ‘_’ button.
- Create a new tall table from the menu by clicking on Window -->New Tall Window -->Table. A new table will appear on the right with two columns for Time(s) and Radiation(count/int).
- Adjust the height of the tube above the source so that the count rate is in the range of 50 - 100 per second.

- Resize the table to maximize your viewing area by clicking and dragging its left edge till only the two columns are visible with no extra gray space in the table window

Collection and Analysis of Data, Part I

1) Go to Setup, Data Collection, Sampling. Change the Experiment Length to 99 seconds the Count Interval to 1 second, then click OK. Press the collect button. The computer will begin counting for one second intervals, and will display the number of radiation counts for each interval in a table and in the histogram. Once you have adjusted the tube to the desired height, click Stop to end data collection. (The number of data points that is collected is not calculated correctly by the program, instead it is one more than desired. So if one wants 40 points, one should subtract the number of Count Interval seconds from the total time that, according to the computer, should give you 40 points.)
Set the horizontal range on your histogram to [0, 2 x average count rate].

2) Start the Experiment by hitting Collect button. **During the collection do not change the histogram's scale!** **<u>Do Not Move The Sample Or Detector During the remainder of the lab., If you do, you will have to start over.</u>** **(If you are innately clumsy and likely to inadvertently nudge things during an experiment, you may want to take some advance taping procedures before starting.)**

3) Write a description of what the computer is doing (include a sketch of the histogram in your lab book) and what you are observing. Tell what is being graphed and what each axis represents. How does the pattern of vertical bars change as time passes?

4) Record the first 10 data points in your journal in a table as shown below. Calculate the mean (average) number of counts per second. Then calculate and record the absolute value of the difference between each reading and the mean. Calculate the squares of the differences, find the average of that column, and take the square root of the result. The final result is called the standard deviation and is a measure of the variation of the data from the mean value. Record all calculations in table in your lab journal.

Data Point	Total Time (s)	Counts/1 s	Difference	(Difference)^2
1	#########	#########	##############	##############
2	#########	#########	##############	##############
….	#########	#########	##############	##############
9	#########	#########	##############	##############
10	#########	#########	##############	##############
		Mean: ######		Mean of Diffs squared: ###########
				Standard Dev.: ###########

5) Now check your calculation of the standard deviation by having your calculator do all the work: [For example, if you have a TI-83+, record your count rate values in a list; then go to STAT, CALC; do 1-Var Stats on the appropriate list. One of the values (s or S: which?) in the displayed results should match your calculation of the standard deviation in part 4 above. In the future, use this calculator short cut for calculating standard deviation and mean, and don't bother with the long, drawn-out process using the table.

6) When the counting experiment is completed:

a) Where does the mean value of the data appear on the graph? Where (or how) does the standard deviation appear on the graph?

b) Obtain the mean and standard deviation for your 100 counts by opening the Radiation vs. Time graph that you minimized when you first opened the software. Use the mouse to select your entire data set on that graph, by left clicking at the leftmost data point, then holding the mouse button down and dragging across the screen to the rightmost data point. Then go to Analyze, Statistics. A new box should appear in your graph, telling you the mean and standard deviation.

c) Record (in your lab journal) and compare the mean and the standard deviation of the first 10 values of your data set (calculated in #3 above) to the mean and standard deviation of the entire data set.

d) Obtain a printed copy of your histogram for each partner. Before printing, make the largest number on the horizontal axis be approximately twice the value of your mean number of counts. Select a nice round number, though, for this end scale value. The left edge of the horizontal axis should show 0. **But make sure that all of the data fits on the screen (and therefore on the printed copy).** Add "100 Count Intervals, each for 1 second" to the title on the printout. (Each partner does this.) Write out the mean and the standard deviation at the bottom the printout. Tape this printout securely into your lab book on a left blank page.

At this point, go to part II to get that experiment started. Then return here to complete the rest of the calculations.

e) Determine the Standard Deviation of the Mean (SDOM) for your data from the standard deviation σ of the whole data set. The SDOM = $\sigma / \sqrt{N}$, where N is the number of data points in your sample. The SDOM represents the uncertainty in the value of the mean for the data collected. When scientists publish a data result, they report the mean value of their data as the result and the report the SDOM value as the uncertainty in that result. However, the SDOM does NOT show up visually on a histogram of a measured data. Why is it fair to say that the uncertainty in the value of the mean is smaller as more data is collected?

f) . On the printout for part 1, mark and labelthe location of the mean of the counting rate on the horizontal axis. (Each partner does all of these steps on his/her own printout.) Also show and label, with a horizontal arrow, the range of count rates from

a) (mean – 1 σ, mean + 1 σ)
b) (mean – 2 σ, mean + 2 σ)
c) (mean – 3 σ, mean + 3 σ)

g) Use your histogram to make a table showing the number of your data points (percent) that fell within each of the 3 ranges listed above.

Part II

1) Now repeat the experiment with Experiment Length set to 299 seconds but keep the Count interval at 1 second. Leave the horizontal screen settings the same as those you used for the printed copy in part I, but increase the maximum range on the vertical axis by a factor of 3.

2) Once the experiment of part II is complete, obtain the mean and standard deviation (as in part 6b above).

3) Again obtain a printout (as in 6d above). Make sure that the horizontal range is exactly the same as on the printout obtained for Part I. Add "300 Count Intervals, each for 1 second" to the title on the

printout. Write out the mean and the standard deviation at the bottom the printout as before. Tape securely into your lab book on the page opposite the previous graph.

At this point, go to part III to get that experiment started. Then return here to complete the rest of the calculations.

4) Compare your histogram from Part I with that of Part II: how is the Part II histogram different from the Part I histogram? Is the mean value the same? Is the standard deviation the same?

5) One lesson to learn from Parts I and II is that the data are randomly scattered around the mean with the same standard deviation in both experiments since we did not change the way that we made the measurements.

6) Again calculate the standard deviation of the mean (see part 6e in part I). Why is the SDOM smaller in Part II than in Part I? What does it mean that the SDOM is smaller in part II?

Part III

1) Now set the Experiment Length to 290 seconds and the Count Interval to 10 seconds. For the histogram, set the horizontal range from 0 to a value 10x that used in the two previous graphs. (Do you see why?) The vertical range (for frequency) should be set from 0 to 4 or 5.

**IMPORTANT: When you are done using the Geiger counter, set its switch to OFF.
Return the radioactive sources.**

2) As in the two parts previous, obtain and record the mean and the standard deviation after the experiment is finished.

3) As before, obtain a printout, but make sure that the maximum value on the horizontal scale is exactly 10 times that of the previous printouts. Again adjust your title and write out the mean and the standard deviation at the bottom the printout as before.

4) Because the counting interval in part III was 10x longer than the intervals in parts I and II it is not fair to compare the mean and standard deviation values unless we convert both of these values in part III to the same units as for parts I and II. After doing so, compare mean and standard deviation values.

5) Compare your histogram to those from Parts I and II: how are they different?

6) The total duration of your Part III experiment was the same as the duration of your Part II experiment. Why are the counts values in Part III clustered more closely around the average value than in Parts I and II?

Summary Analysis

1) In an organized table, summarize, for the three data collection parts, the average (or mean) count rate and the standard deviation with all values in the same units (i.e., counts per 1-second interval).

2) Why would it be fair to characterize the standard deviation σ of part III data as a standard deviation of the mean (even though we did not calculate such a value in part III)?

3) Give at least one way to reduce the SDOM of your measured value of the mean of a data set.

CONCLUSION