Exercise #5: Time Distribution of Counts – Temporal *Interval* Analysis

Hans Geiger and Ernest Marsden collected experimental data on radioactive materials at the University of Manchester in the early twentieth century. Under the direction of Ernest Rutherford, their experiments provided the first experimental evidence of the nucleus. Their data collection methods were similar to those that will be explored in this experiment – namely, taking the elapsed times between radioactive events as observed on a phosphorescent scintillator. Geiger and Marsden measured time intervals with a stopwatch. The rates we deal with in this experiment are much higher, so we seek an accurate and fast electronic means of data collection.

i. For this portion of the experiment you *must* use the functionality of the microcontroller – no other instrument in the lab is capable of autonomously collecting timing data between events!).

ii. Choose a *duration* for your experiment (the default is 1000ms = 1 second), in Henry's code, which you'll be using *in **INTERVAL** counting mode* instead of the ***FREQUENCY*** counting mode, through the use of a different *button switch*, as noted in the next step.

iii. Open the Serial Monitor and an Excel spreadsheet. Click in the cell where you want data entry to begin, *then* click on the particular **button switch** that can toggle a connection between ground and **pin 1** of the Teensy to commence data collection. The screen should populate with time-between-counts, reported in *micro*seconds, over the course of ten seconds. To *stop* your data run, click the *button switch* that began your run. Import this data (*tip*: use CTRL-A to select all data) into your favorite data analysis application.

Statistical Analysis:

- For a valid dataset, create a histogram, *complete with error bars*. Change the plot to a ln-linear scale. It is best to display this data as a *scatterplot*, instead of the default *bar chart*.
- *Where* data is truly random and exhibit *Poissonian* statistics, the limiting distribution should be *exponential*. Linearize your data and, where appropriate, find the slope and, critically, the y-intercept. (What do these *mean*? See Taylor Problem 5.6!!)
- Given an *adequate* fit, the mean can be calculated in three different ways: via statistics, the y-intercept, and the slope of your exponential fit. Discuss the relative merits of each.
- Report the mean and its associated uncertainty with the correct number of significant figures.

Additional Exercises:

The parameter space to *explore* in this lab is extensive. Some suggestions:

a. Extend your previous data sets to ***think further about the "dead time" of your detection circuit***. (Earlier, by plotting, the pulse "decay" as a function of resistance, you should have experimentally determined the capacitance of the photodetector via $\tau = RC$, for a given V_bias.)

b. Measure the "*dark count rate*" of pulses, by completely covering the photodetector. This data can be used to subtract a "***background***" from your data (see Taylor Section 11.4).

c. Create a constant source of illumination using an LED. Measure the count rate as a function of LED Current and/or luminous intensity.

d. Estimate the *quantum efficiency* of the photodetector.

e. Investigate the effect of *temperature* on count rate.

f. Investigate the *spectral response* of the photodetector.