Physics 116C Spring 2006: Quiz 1

4/21/2006

There are 3 problems and 50 points. Give reasoning for full credit. Do your work on this paper. Be sure to put your name on your paper. You may refer to the texts by Essick and Bevington.

1. \( \approx 10 \) points A particle detector has a background counting rate of 0.200 counts/s. The counter was reset and turned on for 20 s. Zero counts were recorded in this interval.

   (a) What was the expected number of counts?
   \[
   \mu = 0.200 \text{ counts/s} \times 20 \text{ s} = 4 \text{ counts}
   \]

   (b) What probability distribution is appropriate for this process?
   \[\text{Poisson}\]

   (c) Find the probability for this outcome assuming the counter was functioning and the background rate was unchanged.
   \[
P(x=0) = \frac{\mu^x e^{-\mu}}{x!} = \frac{4^0 e^{-4}}{0!} = e^{-4} = 0.018
   \]

2. \( \approx 28 \) points Alice and Bob are students making independent measurements of the mean life of a radioactive isotope of Calaggium (one of the exceedingly rare earth elements).

   (a) Near the beginning of the experiment Alice measures \( N = 1600 \) counts in an interval \( \Delta t = 10 \text{ s} \) with negligible background. She wants to plot a graph of \( y = \ln N \) vs. \( t \) with errors. Estimate \( \sigma_y \) for this point.
   \[
   \sigma_y \approx \sqrt{\frac{2y}{2N^2} \sigma_N^2} = \sqrt{\left(\frac{1}{N}\right)^2 \sigma_N} = \frac{1}{40} = 0.025
   \]

   (b) Bob finds the mean life \( \tau \) of the Calaggium isotope to be \( \tau_B = 10.50 \pm 0.08 \text{ hours} \). The accepted value is 10.62 hours. Find the probability for a deviation this large or larger from the accepted value (in either direction) assuming the errors were Gaussian. Give a numerical answer based on Table C.2 in Bevington.
   \[
   z = \frac{|x - \mu|}{\sigma} = \frac{10.50 - 10.62}{0.08} = 1.5
   \]
   \[
P = 0.866 \text{ to be within } \pm 2z,
   \text{Probability of exceeding } \pm 2z = 1 - P = 1 - 0.866 = 0.134
   \]

   (Problem continues on next page)
(c) Alice and Bob want to combine their measurements of the mean life \( \tau \). Alice measured \( \tau_A = 10.65 \pm 0.06 \) hours while Bob found \( \tau_B = 10.50 \pm 0.08 \) hours. Give formulas for the combined \( \tau \) and its error. You do not need to evaluate them.

\[
\tau_C = \left[ \frac{\tau_A}{\sigma_A^2} + \frac{\tau_B}{\sigma_B^2} \right]^{-1} \left( \frac{1}{\sigma_A^2} + \frac{1}{\sigma_B^2} \right)^{-1} = 10.60 \]  
\text{(combined value)}

\[
\sigma_C = \left[ \frac{1}{\sigma_A^2} + \frac{1}{\sigma_B^2} \right]^{-1/2} = 0.048 \]  
\text{(error of combined value)}

3. \( \approx 12 \) points) A student did a counting experiment, repeatedly measuring the number of counts in a 10 s time interval from a long-lived radioactive source. There were 100 trials, each producing a number of counts \( i \) ranging from 0 to 10. A histogram was made of the results. The bin contents were put in a LabVIEW array \( [h_i] \) \( 0 \leq i \leq 10 \) where, for example, \( h_3 = 12 \) means \( i = 3 \) appeared 12 times in the 100 trials. The average number of counts \( \langle i \rangle \) is given by

\[
\langle i \rangle = \frac{1}{N} \sum_{i=0}^{10} ih_i
\]

where \( N = \sum_{i=0}^{10} h_i = 100 \).

You are given the \( h_i \) array as input. Starting with the skeleton block diagram below, show how to use a for loop and other common LabVIEW VI's to calculate \( \langle i \rangle \). (Indicate array variables with heavy lines.)

![Block Diagram](general comment - not required for quiz!)}