1. Consider a 9-stage photomultiplier tube which is operating at a voltage of 1100V and has a bi-alkali photocathode. The secondary emission factor ($\delta$) at 1100V for this PMT is $\delta = 3.7$.

a) How many electrons (on average) will be collected for every photoelectron emitted by the photocathode, assuming 100% collection efficiency?

b) Suppose we observe a current of 83 nA at the output of the PMT when the PMT is illuminated by a light source emitting at 550 nm. How many photons are hitting the photocathode on average each microsecond? Recall that 1 C = $6.24 \times 10^{18}$ electrons and use the QE chart above.
(question continued from page 1)

c) We can combine the PMT with a crystal of NaI doped with Thallium (Tl) to measure gamma ray energies. The gamma rays scatter electrons in the NaI(Tl) to create a shower which excites the crystal through ionizations. NaI(Tl) produces about 40,000 photons for each MeV of energy deposited in it. If we observe pulses of total charge 50 pC, what gamma ray energy is incident on the crystal? You may assume the scintillation photons are all 550 nm.

d) Given the number of photoelectrons, what width (uncertainty) do we expect for the energy? You may assume this is a Poisson process.

e) Suppose the HV drifts from 1100V to 1125V without our noticing. What type of error does this induce and how large is that error?