Exam 2, 3 December 2oo2
TAKE HOME – due Thursday, 5 December 2oo2, 8:30AM

1. (10 pts total) A ten-stage photomultiplier tube has a single dynode multiplication factor (δ) of 5.
   (a) (1pt) What is the gain of this PMT?
   (b) (3pts) For a single photoelectron incident on the first dynode, what is the expected standard deviation in the number of secondary electrons emitted from this dynode?
   (c) (3pts) What is the relative error (σ_N/N) in the number of electrons that will reach the anode from the pulse started with one photoelectron?
   (d) (3pts) What is the relative error (σ_N/N) in the number of electrons that reach the anode in a DIFFERENT pulse that is started with 100 photoelectrons?

2. (10 pts total) A cylindrical gas proportional counter was used to detect charged particles that deposited 5.0 MeV in the gas. The tube had an anode radius of 0.005 cm, a cathode radius of 5.0 cm, and was filled with P-10 gas at 1.0 atm pressure. If the applied voltage was 2 kV, then:
   (a) (5 pts) Calculate the multiplification factor for this detector.
   (b) (5 pts) Estimate the amplitude of the detector pulses into a capacitance of 100 pF.

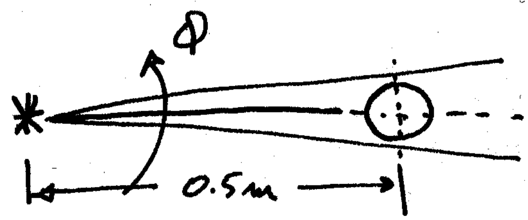
3. (10 pts) Estimate the resolution for the full-energy peak for a 1.0 MeV photon that is detected in PbI_2, a novel type of semiconductor detector material. This material has a density of 6.16 g/cm^3, a bandgap of 2.6 eV, a Fano-factor of 0.08, and an electron-hole pair creation energy of 7.68 eV. How would you expect the fraction of counts in the full-energy peak of a 1.0 MeV gamma ray detected with PbI_2 to compare with that detected with a HPGe detector?

4. (10 pts) Calculate the expected amplitude in mV of the signal pulse expected from a standard 3"x3" NaI(Tl)–PMT combination under the following conditions using any auxillary data from the text as necessary:
   Radiation engery loss in crystal: 1.00 MeV
   Light collection efficiency: 80%
   Photocathode quantum efficiency: 20%, PMT electron gain: 10^4
   Anode capacitance: 100 pF, Anode load resistance: 50Ω.

   Also, explain if the observed pulse shape will be effected by the (a) electronics, (b) the scintillation time-constant, or (c) the primary radiation.

5. (10 pts total) A student would like to measure coincidences between the two γ rays following the beta decay of ^{60}Co. A 10 μCi ^{60}Co source was placed midway between two identical 3"x3" NaI(Tl) detectors.
   (a) (1pt) Make an estimate of the peak efficiency using fig. 10.25
   (b) (5pts) What distance should the detectors be placed to obtain a rate of true coincidences of 100/sec?
   (c) (4pts) What is the rate of accidental coincidences in this setup if the total coincidence resolving time, τ=4μs?

6. (10 pts) The NSCL SeGA array consists of a set of segmented germanium detectors (right cylinders, 7 cm diameter x 8 cm long) that are irradiated from the side. Make an accurate graph (not sketch) of the attenuation of a 2.0 MeV γ ray incident perdendicular to the cyrindrical axis from a source 0.5 m away as a function of the angle ϕ defined in the sketch below. For this graph you will need the attenuation coefficient for 2 MeV γ rays in germanium.



7. (10 pts) The NSCL safety system relies on a proportional counter that contains a BF_3 filled tube in the center of parafin filled 20-liter bucket with a cadmium sheet on the outside of the parafin. An electronic circuit supplies a bias to the tube and only records pulses above a certain threshold. Explain what type of radiation this device is sensitive to and the role of each component. Why, for example, is the pulse-height above the threshold ignored?

8. (10 pts) The present NSCL data acquisition system relies on successive approximation ADC's that require approximately 10μs to complete the conversion of all analog signals into digital words. The ACS's reside in CAMAC crates serviced by a code running in a LINUX computer (through PCI/VME and then VME/CAMAC interfaces). The time to store a data word from the module in the computer memory is approximately 3μs. Estimate the deadtime per event if this system is used to readout an experiment that has ten parameters (ten data words). Estimate the fractional deadtime if this ten-parameter experiment is running at the rate of 200 events/sec. At what event rate will the system reach a fractional deadtime of 0.50 (at ten words/event) ?

9. (20 pts) Describe the detector system that you plan to use to collect the data for your dissertation. Include a description of all of the major features, and be sure to address all of the following points:

   (a) The type of radiation to be observed, (type, energy, etc.)
   (b) The active volume of the radiation detector, (approx. size, material)
   (c) The interaction of the radiation in the material (mechanism, approx. ΔE)
   (d) The observed signal from the detector (generation mechanism, approx. size, shape, resolution)
   (e) The signal processing (amplification, shaping, size at various points)
   (f) The signal recording (triggering, converters, resolution, etc.)