NE-512 Final Exam  December 15, 2003

All necessary constants, values, and graphs are located either in the Chart of the Nuclides, Radiological Health Handbook, or have been attached to the exam.

Some useful information:

\[ \varepsilon_0 = 8.854 \times 10^{-14} \text{ F/cm} \]
\[ q = 1.62 \times 10^{-19} \text{ C} \]

Air density = 1.25 mg/cm\(^3\)

Argon density = 1.78 mg/cm\(^3\)

Si density = 2.33 g/cm\(^3\)

For Si, \(\varepsilon_s = 11.9\)

Ge density = 5.32 g/cm\(^3\)

For Ge, \(\varepsilon_s = 16\)

CdTe density = 6.06 g/cm\(^3\)

For CdTe, \(\varepsilon_s = 11\)
1. True or False (2.5 pts each)

   A. T ______
   Ion-chambers are often used in high radiation areas.
   F ______

   B. T ______
   Beta particles are emitted from a radiation source with a
   continuous spectrum of energies.
   F ______

   C. T ______
   The acronym TLD, in radiation dosimetry, means “thermal
   luminescent dosimeter”.
   F ______

   D. T ______
   Alpha particles are attenuated exponentially as they pass through a
   medium.
   F ______

   E. T ______
   NaI(Tl) detectors must be cooled to reduce thermal leakage current
   during operation.
   F ______
2. Multiple Choice (2.5 pts each)

A. Deadtime associated with the operation of radiation detection systems is greatest for

(1) HPGe Detectors _____ (2) GM Counters _____
(3) Gas Proportional Counters ____ (4) Scintillation Counters ____
(5) Ion Chambers ____

B. An 80 keV gamma ray will most likely interact in a NaI(Tl) detector through

(1) Compton Scattering_____ (2) Annihilation _____ (3) Photoelectric ____
(4) Pair Production ____ (5) None of these ____

C. A large volume detector, when compared to a small volume detector, (NaI or Ge for instance) will show a larger number of counts in the __________ region compared to the counts in the __________ region.

(1) Pair production, Compton _____ (2) backscatter, full energy_____
(3) relativistic, classical_____ (4) full energy, Compton_____
(5) None of these ____

D. The single escape peak for a 1.7 MeV gamma ray in a Ge detector falls at what energy on the spectrum?

(1) 1.022 MeV _____ (2) 511 keV_____ (3) 1.189 MeV ____ (4) 678 keV ____
(5) None of these ____

E. With increasing gamma ray energy, the gamma ray energy resolution (in keV at FWHM) for an HPGe detector

(1) improves ____ (2) worsens _____ (3) stays the same _____
(4) unpredictable ____ (5) None of these ____
Work six (6) of the following seven (7) questions. Label clearly “SKIP” for the problem that you choose to OMIT. – SHOW ALL WORK! If you use additional paper, then attach your work sheets to the test and turn them in also.

3. Problems (12.5 pts each)

   A. i. Draw the gas-filled detector pulse height curve for different sources emitting beta, gamma, and alpha particles. Label the axes, identify the features, and briefly describe what causes them.

   ii. Explain why a quenching gas is used in:

      a. Proportional Counters

      b. Geiger Mueller counters.
B. You have a $^3$He gas counter to detect fast neutrons that are pulsed from a spallation source. A chopper pair is used such that only neutrons of 1.5 MeV can reach your detector. Sketch the expected pulse height spectrum. Label the all features and energies of those features. Explain why the features appear.
C. You are using the arrangement shown in the figure to take measurements. The CdTe detector is a cylinder 1 cm in diameter and 2 cm long. The $^{137}$Cs source was calibrated to be exactly 20$\mu$Ci on December 15, 1958.

$n = 10^{10}/\text{cm}^3$ for detector bulk  
$p = 10^{18}/\text{cm}^3$ for contact  
$V_{bi} = 0.7$ volts

i. The detector is biased at 1000 volts. How long must you count to reduce the counting error to 1% for the total counts in the pulse height spectrum.
D. Gamma rays from a $^{54}\text{Mn}$ source are attenuated through a Pb shield as shown below.

Calculate the absorber thickness if the observed counts are:

- Absorber present: 3050 counts/30 minutes
- Absorber removed: 25060 counts/10 minutes

Background is negligible. Include the standard error of the thickness you find.
E. Describe the advantages and disadvantages of the following detectors:

i. NaI(Tl) scintillation detectors

ii. High Purity Ge detectors

iii. Gas-filled proportional counters
F. You have the following arrangement with a Si surface barrier detector placed in a vacuum chamber. A source was placed 7 cm away from the detector. Before the detector is operated in vacuum, the chamber was thoroughly purged with argon to remove all of the air. Assume that the Au window on the detector is negligible. At what pressure (ATM) must the vacuum chamber be reduced before the alpha particles will begin to be detected by the Si detector?
G. You have two beta particle sources and you are trying to determine the dead time of a detector. You find the following counts under the following conditions:

G1 = 12,050 cpm for source one  
G2 = 11,700 cpm for source two  
G12 = 20,800 cpm for both sources

Each measurement was made for a one-minute duration. Background is negligible. Assume that the dead time is significant. Show all work and explain assumptions made.
4. Extra Credit (30 possible points added to the total score)

You have four detectors that you will operate in the configuration shown below:

The LLD is set at 50 keV equivalent for all detectors. Detectors A, B, and C are NaI(Tl) detectors, each rated as 2 in diameter x 2 inches long. Detector D is an HPGe detector rated as 3 in diameter x 3 inches long. Detectors A and B are operated in coincidence, meaning that only when radiation events occur in both detectors at the same time (within a microsecond, let’s say), will a count be recorded in the pulse height spectrum from the devices. The source is a $^{24}\text{Na}$ pellet produced in a nuclear reactor after activation only 10 minutes before your final began, and it was rated at 10 $\mu$Ci at that time.
i. Draw the spectrum accumulated by detector A. Label all features and clearly show all energies of the features in the spectrum.

ii. Draw the spectrum accumulated by detector D. Label all features and clearly show all energies of the features in the spectrum.
iii. Draw the spectrum accumulated on detector C. Label all features and clearly show all energies of the features in the spectrum.
Extra work space -