Fall 2005 Qualifying Exam
Theoretical Health Physics

Directions: Please start each exam question answer on a new page AND use only one side of each page. Place your letter in the top right hand corner of each page you submit. When turning in exam, please staple answers to each exam question separately with the question sheet on top and be sure all is in numerical order. Remember to number pages consecutively, e.g., 1-1, 1-2.

1. (15 minutes) A worker was exposed to airborne activity ($^{137}$Cs) in a room when the chemical hood in which he is working failed. An air monitor in the room indicated that the air concentration increased instantaneously to $5 \times 10^7$ Bq/m$^3$ and remained at that level. The worker was assumed to be in the room for 20 minutes before evacuating the area. Calculate the following (listing all assumptions):
   a. the estimated intake from this exposure.
   b. the estimated uptake from this exposure (assume that the material is class D and that $f_1 = 1.0$).
   c. the committed dose equivalent to the lungs and red bone marrow for this exposure.
   d. the committed effective dose equivalent for this incident.

Data:

- $\text{DCF} \quad \text{gonads} = 8.76 \times 10^{-9}$ Sv/Bq
- lungs = $8.82 \times 10^{-9}$ Sv/Bq
- $b$ surface = $7.94 \times 10^{-9}$ Sv/Bq
- remainder = $9.12 \times 10^{-9}$ Sv/Bq

- $\text{breast} = 7.84 \times 10^{-9}$ Sv/Bq
- $\text{r marrow} = 8.30 \times 10^{-9}$ Sv/Bq
- thyroid = $7.93 \times 10^{-9}$ Sv/Bq
- effective = $8.63 \times 10^{-9}$ Sv/Bq

- ALI = 6 MBq
- DAC = 0.002 MBq/m$^3$

2. (15 minutes) Draw a diagram depicting the change of RBE with LET for a specific endpoint in mammalian cells irradiated by helium ions under normal ambient conditions. Next draw a diagram of the variation of RBE with LET under conditions where free radical scavenging is nearly 100%. Be sure both diagrams are labeled correctly and explain any differences or similarities between the two diagrams.

3. (15 minutes) Compare and contrast the ICRP 30 Respiratory Tract Model to the ICRP 60 Lung Model.
4. (10 minutes) Consider 2 materials dispersed in ordinary room air:
   (1) a short half-life radioactive noble gas is present that decays to a second
   radioactive nucleus
   (2) a dense, nonradioactive aerosol of particles over 2 μm

   Consider the following situations and provide answers:
   (a) (3 minutes) If the gas from (1) enters a closed room, discuss the
   pathways for its health impact.
   (b) (3 minutes) If materials from (1) and (2) are simultaneously present,
   discuss the pathways for health impact.
   (c) (4 minutes) Which presents the greatest hazard for unprotected
   workers, situation (a) or situation (b)? Why?

5. (10 minutes) A monodisperse aerosol of $10^5$ cm$^{-3}$ particles of $10^{-5}$ cm radius
   has an activity of $10^{-3}$ Bq/cm$^3$ due to a radionuclide whose half-life is 100 days.
   If you assume each particle contains no more than 1 radioactive atom, what fraction
   of the particles is radioactive?

6. (15 minutes) Estimate the dose to a monolayer of cells (isolated in space) that is
   hit by a beam of charged particles from an accelerator. Assume that the stopping
   power of the particles is 10 keV/micrometer and the beam current is 1 microamp,
   uniformly distributed over a 1 cm square area and the exposure time is 10 seconds.
   List the assumptions that are necessary for you to do this calculation.

7. (10 minutes) Pulse shape discrimination can be used to separate neutron and
   gamma ray components of the dose detected by both liquid scintillation detectors and
   high pressure hydrogen proportional counters. Explain the mechanism leading to
   differences in the pulse shape for photon and neutron events in each type of detector
   and sketch the pulse shapes you expect to see (be sure to label the detector type and
   radiation type).

8. (15 minutes) A one-minute count of a source gives 85 counts. The source is
    removed and a one-minute count of background yields 11 counts. The total counting
    time is fixed at 60 minutes. Unfortunately, the electronic timer is not working so you
    use a stopwatch to time your counts. The standard error of the stopwatch can be
    taken to be 2% of the elapsed time.
   a) (3 minutes) What is the expected net count rate from the source?
   b) (12 minutes) What is the expected error in this net count rate due to the factors
      stated above?
As shown in the schematic above, a 10-MeV photon has a Compton interaction in the volume of interest, $V$, producing a 3 MeV secondary photon. The Compton electron while traversing the volume produces a 1 MeV bremsstrahlung photon, and exits the volume with 2 MeV. After leaving the volume, the electron produces a 100 keV x-ray. What is the energy imparted, $\varepsilon$, the energy transferred, $\varepsilon_t$; and the net energy transferred, $\varepsilon''_t$ in volume $V$?