# MEPH 569 – 032 – FINAL EXAM

## PR - 1

1. With broad-beam "poor geometry" attenuation the exposure rate outside a certain shield is 100 mR/h due to the un-collided photons alone in a mono-energetic beam. If the buildup factor is 3.8 then the total exposure rate is:

   a) 2.24 mR/h
   b) 26.3 mR/h
   c) 200 mR/h
   d) 380 mR/h
   e) 3.8 R/h

2. A certain radioisotope is produced by thermal neutron activation of a sample containing $5 \times 10^{22}$ target atoms with an activation cross section of 2 barns. The (constant) neutron fluence rate is $10^{11}$ $cm^{-2}$ $s^{-1}$. the saturation activity in disintegrations per second is

   a) $10^{10}$
   b) $5 \times 10^{10}$
   c) $10^{11}$
   d) $5 \times 10^{11}$
   e) $10^{12}$

3. For a radionuclide with a decay constant of 0.693 h-1, the fraction of atoms that decay in 2 h is expected to be

   a) 0.167
   b) 0.250
   c) 0.500
   d) 0.667
   e) 0.750

4. In an experiment, some seeds are placed near a gamma source, having a decay constant of 10 $h^{-1}$. The initial dose rate at the position of the seeds is 100 rad/h. If the seeds are left there for a week, the total dose they receive will be

   a) 1000 rad
   b) 100 rad
   c) 10 rad
   d) 1 rad
   e) not determinable from this information.

5. A worker received a lung dose of 12mGy from alpha radiation from an internally deposited radionuclide and a 40 mGy uniform, whole-body dose from external gamma radiation. What is the equivalent dose to the lung ?

   a) 100 mSv
   b) 160 mSv
   c) 220 mSv
   d) 280 mSv
   e) 1040 mSv

6. A worker received a lung dose of 12mGy from alpha radiation from an internally deposited radionuclide and a 40 mGy uniform, whole-body dose from external gamma radiation. What is the effective dose ?

   a) 47.2 mSv
   b) 52.0 mSv
   c) 54.4 mSv
   d) 64.0 mSv
   e) 68.8 mSv

7. A worker has been exposed to fast neutrons and received an acute dose of 500 rem. What symptoms are likely to receive?

   a) Blood changes only
   b) Blood changes and the hemopoietic syndrome only
   c) Blood changes, hemopoietic syndrome, and gastrointestinal syndrome
   d) Gastrointestinal syndrome only
   e) Gastrointestinal and central nervous system syndrome

8. Radiation produces biological effects by

   a) Direct excitation and inonization of molecules and production of radioactive materials that poison the body
   b) Direct excitation and ionization of molecurles and indirect action of free radicals and hydrogen peroxide
   c) Indirect excitation and ionization of molecules and production of low levels of toxic materials that attack cell walls.
   d) Direct excitation and inonization of molecules and production of excited radicals that decay and ionize water
   e) Ionization and production of free radicals that degrade cell structures at the site of the incident radiation

9. The average annual fatal accident rate in safe industries in the United States is approximately

   a) $1 \times 10^{-3}$
   b) $1 \times 10^{-4}$
   c) $1 \times 10^{-5}$
   d) $1 \times 10^{-6}$
   e) $1 \times 10^{-7}$

10. Which of the following describes the reason for the high sensitivity of a Geiger-Muller tube radiation detector ?

   a) Changes in applied detector voltage have little effect on detector output
   b) Geiger-Muller tubes are longer than other radiation detector types
   c) Any incident radiation event causing primary ionization results in ionization of the entire detector gas volume
   d) Geiger-Muller tubes are operated at relatively low voltages, allowing the detection of low-energy radiation
   e) Space charge effects are minimized, and thus sensitivity is high

11. Which of the following statements best describes how a proportional counter functions?

   a) Some of the ions from primary ionization are collected. No secondary ionization occurs.
   b) All of the ions from primary ionization are collected. No secondary ionization occurs.
   c) All of the ions from primary ionization along with some of the ions from secondary ionization are collected.
   d) All of the ions from primary ionization and secondary ionization are collected.
   e) All of the ions from primary ionization, secondary ionization, and Avalanche are collected.

12. What design features allows neutron detection by a proportional counter?

   a) The detector outer surface is lined with B-10
   b) The detector is filled with $BF_3$ gas
   c) The detector anode is composed of a $B_4C$ composite
   d) The detector is encased in borated polyethylene
   e) The detector is wrapped in a cadmium/polyethylene shield

13. A semiconductor detector acts as a solid-state

    a) Ionization chamber with about 3-4 eV required to produce an ion pair
    b) Proportional counter with about 3-4 eV required to produce an ion pair
    c) Ionization chamber with about 0.5-1.0 eV required to produce an ion pair
    d) Proportional counter with about 0.5-1.0 eV required to produce an ion pair.
    e) Junction detector with about 1-2 eV required to produce an ion pair

14. TLD phosphors that have been effective for measuring neutrons are enriched in which of the following isotopes?

    a) Li-6
    b) Li-7
    c) Be-7
    d) C-13
    e) 0-14

15. Two 5.0 cm long, cylindrical gas ionization chambers, A and B are identical except for their diameters. Detectors A and B are 0.5 cm and 1.0 cm in diameter, respectively. If detector A shows an output current of $1.0 \times 10^{-10}$ amperes when placed in an isotropic gamma field, what theoretical response should be given by detector B when placed in the same field? Neglect detector end effects.

    a) $2.5 \times 10^{-11}$ A
    b) $4.0 \times 10^{-10}$ A
    c) $2.0 \times 10^{-10}$ A
    d) $5.0 \times 10^{-11}$ A
    e) $1.0 \times 10^{-10}$ A

16. A 2.0 Ci point source of Co-60 is located 2.0 m from you. What is the exposure rate at your location?

    a) 0.63 R/h
    b) 1.30 R/h
    c) 2.60 R/h
    d) 3.20 R/h
    e) 4.00 R/h

17. The average energy of a beta-ray spectrum is what fraction of its maximum energy?

    a) $\frac{1}{6}$
    b) $\frac{1}{5}$
    c) $\frac{1}{4}$
    d) $\frac{1}{3}$
    e) $\frac{1}{2}$

18. what is the absorbed dose rate in water due to a monodirectional flux of $1.0 \times 10^4$ photons/cm$^2$-s which have a stopping power of 300 MeV/cm?

    a) 0.48 mrad/s
    b) 0.4 mrad/s
    c) 48 mrads
    d) 480 mrad/s
    e) 4.8 rad/s

**PR - 2**

A certain proportional counter uses a gas that has negligible response to thermal neutrons. The inside walls of the counter tube are lined with boron, containing the isotope B-10 (19.8 % abundant), which has a large cross section (3840 barns) for absorbing thermal neutrons. The resultant ($\alpha$, n) reaction leaves a lithium nucleus, either in a single excited state or its ground state. The two modes of reaction, their resultant energy releases (Q values) in MeV, and frequencies are:

$$ {}^{10}_{5}B + {}^{1}_{0}n \rightarrow \begin{cases} {}^{7}_{3}Li^{*} + {}^{4}_{2}\alpha, & Q = 2.31, \quad 96\% \quad (1) \\ {}^{7}_{3}Li^{*} + {}^{4}_{2}\alpha, & Q = 2.79, \quad 4\% \quad (2) \end{cases} $$

For such a detector exposed to thermal neutrons, sketch the pulse-height spectrum (relative number of counts vs energy) when the boron layer on the inside wall of the tube is very thin

**PR - 3**

A short lived radionuclide is counted for a time long compared with its half-life. The detector registers 943,028 counts from the sample, which decays away completely. What is the standard deviation in the original number of atoms present in the sample if the counting efficiency is (a) 100 % (ie. Every disintegration is registered as a count)? (b) 60.0%?

**PR - 4**

A flat lead shield is to be placed normally in the path of a parallel beam of 1-MeV photons. The exposure rate in the beam, 50 R/hr, is to be reduced to 2.5 mR/hr by the shield. What thickness of lead is required? The attenuation coefficient of lead for 1-MeV photons is $\mu = 0.80/cm$. Buildup factors B for various shield thicknesses x are given in the table in terms of the number of relaxation lengths $\mu x$.

| **Number of Relaxation Lengths, $\mu x$** | **Buildup Factor, B** |
|---|---|
| 1 | 1.38 |
| 2 | 1.68 |
| 3 | 2.18 |
| 7 | 2.80 |
| 10 | 3.40 |
| 15 | 4.20 |

**PR - 5**

The mass attenuation coefficient for concrete (density = 2.35 $g/cm^3$) for 600-keV photons is 0.80 $cm^2/g$. (a) What is the probability that a 600 keV photon, normally incident on a thick, flat concrete shield, will reach a depth of 15 cm without having an interaction? (b) What is the probability that an incident photon will reach a depth of 30 cm without interacting? (c) What is the probability that a given photon, having reached a depth of 15cm without interacting, will travel an additional 15cm without interacting? (d) Calculate the mean free path of the photons.

**PR - 6**

(a) By what kinds of interactions do neutrons transfer energy to matter? (b) what are the principal mechanism by which neutrons deliver dose to soft tissue?

**PR - 7**

Figure 1 shows a schematic top view of an X-ray facility. A diagnostic machine, operated at 150 kVp with a maximum current of 120 mA, is used an average of 22.1 min/d, 5 d/wk. The horizontal beam is always pointed in the direction of the sidewalk. (a) Calculate the thickness of lead shielding needed for the primary protective barrier (b) Calculate the thickness of additonal lead shielding needed to make a secondary protective barrier for the book store.

Given Data:

Half-value layer (HVL) of lead at 150 kVp = 0.30 mm, HVL of concrete at 150 kVp = 2.24 cm.
Average density of concrete = 2.35 $g/cm^3$
Density of lead = 11.4 $g/cm^3$
Density of plaster = 1.54 $g/cm^3$