22.01 Problem Set 8

1 What's In Your Toenails? (20 points)

Using the same methodology as in Problem Set 5, figure out what's in your toenails! You can use the default spectrum on the Canvas site if you don't have one of your own. Elements that we've noticed in some of the spectra include Cr, Fe, Mn, As, and Au, but you may not see every element in every sample. You can use the same background spectra from Problem Set 5, and other useful information about each specimen and the overall irradiation is on the Canvas site.

2 Forbidden Cookies (20 points)

You are given four cookies containing dangerous levels of a high-activity isotope. Each has the same half life, the same concentration, and therefore the same activity. One emits alpha particles, one emits betas, one emits gammas, and one emits neutrons, all at the same energies. You must put one in your pocket, hold one in your hand, eat one, and give one to a "friend." What do you do, and why? **Use your knowledge of stopping power, range, and relative biological effectiveness (tissue and radiation quality factors) to explain.**

3 Toasty Flights (20 points)

How many round-trip flights from Boston to Japan would you have to take to double your yearly background radiation dose? Take the BOS-NRT direct flight as your reference case. Use this handy FAA flight dose calculator to help you: http://jag.cami.jccbi.gov/cariprofile.asp

4 Spooning (20 points)

Estimate the additional dose incurred by spooning (see Figure 1), compared to sleeping alone, for eight hours.

Figure 1: Spooning

Answer: *About 0.01μSv (anything within a factor of two should be just fine)*

5 Inciting Mass Panic with Data (20 points)

Using your Geiger counters, find the most radioactive, *publicly accessible* place wherever you happen to be. Each person (or team of two people) should count at just 1-2 places. Be 95% confident in your measurement to within 10% uncertainty, so we can compare in class! If you go to a public place, be sure to clear your short experiment with any local security, guards, or other officials so you don't get anyone worried.

Hints for the Problems

Spooning

Here, you'll have to perform the following overall steps:

1. Look up the concentrations of radioactive isotopes naturally present in the body. Assume that dogs are basically humans.
2. Decide which of those isotopes will release radiation which could be felt by the adjoining dog.
3. Assume a rectangular, prismatic dog.
4. Determine how much radiation each slice of Dog 1 irradiates Dog 2. Consider:
   (a) The solid angle of a slice of Dog 1's radiation towards Dog 2
   (b) The *self-shielding* of Dog 1, blocking its own radiation from getting to Dog 2
   (c) The amount of radiation coming out of each dog slice, which is actually absorbed by Dog 2
5. Make sure the answer is in Sieverts, by accounting for the masses of the dogs, tissue quality factors, and radiation quality factors.

Knowledge Brings Fear

1. Use your knowledge (and the readings, and the lecture slides) to decide which building materials or altitudes (including negative altitudes) are most likely to harbor radioactive substances, more cosmic radiation, or higher levels of radon. This will help you pick places to go.
2. You'll have to consider the *uncertainty* on a counting rate experiment, and the time it takes to be 95% confident in that measurement to within an error of 10%. Assuming errors in any experiment are normally (Gaussian) distributed, you can claim 68% confidence on a measured count rate plus/minus one standard deviation (σ) of that count rate, and 95% confidence on 1.96σ. The standard deviation on a count rate (r) is defined as follows:

   $$\sigma = \sqrt{\frac{r}{t}} \tag{1}$$

   where (t) is the amount of time for which the measurement was counted. Therefore, you can estimate the time you'll need to count to obtain 95% confidence on a 10% uncertain measurement, if you have a good guess of the count rate:

   $$1.96\sigma = 1.96\sqrt{\frac{r}{t}} = 0.1r \tag{2}$$

   and solve for (t). You can run a short background experiment (just count in your room or wherever) to get a good, first guess at (r).
3. Divide and conquer for more locations! You can work in groups of up to two people, in case not everyone has a working Geiger counter or an Android phone.
4. Be safe and courteous! We don't have the class funds to bail anyone out of jail for sneaking into someplace you shouldn't be. Also, trespassing is wrong.

22.01 Introduction to Nuclear Engineering and Ionizing Radiation
Spring 2024