22.01 Fall 2015, Problem Set 8 (Normal Version)

Due: November 25, 11:59PM on Stellar

November 28, 2015

Complete all the assigned problems, and do make sure to show your intermediate work. Please upload your full problem set in PDF form on the Stellar site. Make sure to upload your work at least 15 minutes early, to account for computer/network issues.

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1 Radiation in the Environment

1. List the five largest *natural* sources of background radiation from living in Cambridge, MA, and what percent of your yearly background dose they comprise.
2. Estimate the increase in background dose per hour from flying from Boston to Japan, over the North Pole.

2 Analytical Environmental Questions

Given a EPA-reported radon activity concentration of 0.4 $\frac{\text{pCi}}{\text{L}}$ in normal air, estimate your increase in background dose if a rain cloud 1km above the ground washes all the radon down to the ground. You may approach this problem in one of two ways: External exposure, or Internal exposure.

For the external exposure approach, consider the shielding of the air, compared to the water (Hint: solve this as an integral problem). You may assume that photon energy loss mechanisms do not apply; that is, attenuated photons are absorbed. You may find it helpful to break up the problem into the following steps:

1. Estimate the radon dose to you, from a volume element of air with activity A at a distance D from you. Account for the number of photons attenuated by air between you and the volume element of air.
2. Integrate this dose in a hemisphere surrounding you to get the total dose. You may want to define a cutoff radius, beyond which effectively no radiation reaches you.
3. Calculate the *aerial activity density* of radon in the lower 1km of atmosphere. This is expressed in $\frac{Ci}{m^2}$.
4. Assume that the radon all washes down to your body level, and approximate yourself as a point source. Repeat (a-b), but this time integrating a disc of air surrounding you, and accounting for a rain volume fraction of 20% during the storm.

For the internal exposure approach, estimate the fraction of radon taken in with each breath (continuing a calculation that we started in class), both normally without rain and when the rain wshes all the radon down to ground level. Make any assumptions about how the radon concentration increases during rain as you need, and try to calculate the amount of radion in each breath that will decay into daughter products while in the lungs. Keep in mind the tissue weighting factor for lungs.

3 Radiation Units

1. Which type of radiation dose unit (Roentgen, Rad, Gray, Rem, Sievert) do you think your Geiger counter is best for directly measuring, and why?
2. Calculate the radiation energy absorbed for a dose of 1Gy to the following organs: skin, eyes, thyroid, brain.
3. A 1Ci source of ^{137}Cs is dropped in NW13 during a 22.09 lab (note, this happened once!!!).
   (a) Estimate the full body dose equivalent in mSv to a student, assuming they ran at a speed of 5 $\frac{m}{s}$ from the source once it was spilled.
   (b) Estimate the total specific energy absorption in Roentgens from this accident.
   (c) Does this constitute a significant radiation exposure? Why or why not?

4 BONUS 25 Point Question

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

Figure 1: Spooning

22.01 Introduction to Nuclear Engineering and Ionizing Radiation
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