PHYS 4134, Fall 2015, Homework #7

Due Wednesday, October 26.

1. Cosmic Rays (and Cancer! Yeah!)

The flux of cosmic ray muons (μ^+ and μ^-) at sea level is roughly 1 $\text{min}^{-1}\text{cm}^{-2}$. The average energy of these muons is 4 GeV/c. We are going to calculate the number of expected lethal cancers in a population of 250 million people that are continuously exposed to cosmic muon radiation for a period of 60 years.

(If you're brave enough you can try this for a while on your own. If not, turn the page over and we will walk through it step by step.)

1.1 Composition of the human body

For a rough estimate let's assume a human body consists of 100% water (in reality it's more like 75%). What are the two mass densities of hydrogen and oxygen in the human body in units of g/cm^3?

1.2 Energy Loss Rate

a) What are the average rates of energy loss for cosmic ray muons in hydrogen and oxygen in units of MeV $cm^2\,g^{-1}$. [Hint: you will have to google for this one. Use the reviews in Chapter 33, "*Passage of Particles Through Matter*", at http://pdg.lbl.gov, the Particle Data Group's PDF files. Note oxygen is not in table 33.2, but you can look at carbon and aluminum for guidance.]

b) Convince yourself that these energy loss rates are approximately constant, no matter whether the muons pass through a human that is standing or lying in bed.

1.3 Energy Deposition Rate

Now you should be able to calculate the total energy deposition rate in MeV $g^{-1}\,min^{-1}$.

1.4 Equivalent Dose

Energy Deposition Rate

a) What is the equivalent dose rate in units of μSv/y.

b) How does this compare to the value that your book states for cosmic rays? [See table 7.3 in the text.]

c) What is the total number of cosmic ray muon-induced fatal cancers in a population of 250 million that are exposed for a period of 60 years? [See table 7.5 in the text.]

2. A standard does of post-operational X-ray therapy (normally given after operations to remove cancerous breast tissue) consists of daily "fractions" of 2Gy, 5 days a week for 5 weeks. Estimate the risk of inducing breast-cancer from this treatment. [See also Table 7.5]

3. Estimate the strength of a ^{60}Co γ-ray souce which would give a does rate equal to that of the natural background (about 2.6 mSv per year) to a person working at a distance of 1.5 m from the source. [^{60}Co emits two γ-rays per disintegration with energies of 1.17 and 1.33 MeV.] [Hint: see Eqn. 7.8]