22.01, Quiz 2, Fall 2015

November 16, 2015

Complete all parts of all problems. Make sure to show your work, partial credit *will* be given for explaining the correct approach, or for showing part of the solution, or for defining unknown, intermediate variables and using them correctly.

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1 Short Conceptual Questions (5 points each)

1.1 Explain the physical meanings of the maximum and minimum impact parameter between a moving charged particle and an electron.

1.2 Write the criticality condition for a homogeneous reactor with one energy group of neutrons. Circle the term(s) that changed when control rods are inserted, and explain why. Which one(s) changed the most, and why?

1.3 Draw three hypothetical mass-attenuation vs. energy curves *on the same graph and axes*, for hydrogen (Z=1), lead (Z=82), and super-kaduper-unubtanium (Z=500).

1.4 Write an expression for the energy difference between the photo-peak and the Compton edge on a typical photon spectrum obtained from a detector.

1.5 Explain why most isotopes don't undergo neutron-induced fission, even though the Q-value for the fission reaction would be enormous (>100 MeV).

1.6 Give five desired traits of an effective moderator for a thermal nuclear reactor, in terms of its nuclear structure, its material properties, and/or its characteristic cross sections.

1.7 Show how the Klein-Nishina cross section yields a Thompson scattering cross section that is symmetric about $\theta = \frac{\pi}{2}$.

1.8 Using the Q-equation, derive the minimum and maximum energy transferred in neutron elastic scattering.

2 Analytical Questions (30 points each)

2.1 Suppose we want to analyze a <u>homogeneous, infinitely-sized</u> reactor with <u>three</u> energy groups of neutrons: fast (E>1eV), thermal (0.025eV<E<1eV), and <u>super-cold</u> (E<0.025eV, <u>with up-scattering</u>). Write the full equations describing the balance between production and loss of neutrons in these three energy groups. Define any terms you need to write your equations.

2.2 Suppose you are choosing how to treat a very small brain tumor, using 40keV x-rays or protons whose energy is tuned to just reach the tumor, at a distance d inside the patient. In either case, it takes M ionizations to completely destroy the tumor. Develop an expression showing the ratio of collateral damage (ionizations outside the tumor) that each type of radiation will produce. Assume humans are made of one substance with a mass attenuation coefficient μ for 40keV x-rays, and some average values for all other relevant quantities (which you should define).