Test 2 for Modern Physics, TTVN.

Please show all your work on these problems. You may use your book and other resources. This is due to Dr. Craig by Apr 4. They can be emailed to dcraig at wtamu.edu (I prefer PDF files) or faxed to 806-651-5255.

1. Problem 13.28 in your text. These equations are useful because they allow you to easily calculate half-lives and decay constants from experimental data, particularly for isotopes with short half-lives.

2. Problem 13.36 in your text (calculate the specific activity of Sm-147).

3. Problem 14.12 in your text, on the effective cross-section for Pb atoms and γs.

4. Problem 14.20 in your text, on the de Broglie wavelength for thermal neutrons.

5. Problem 14.24 in your text (using up all the U-235 in the world), which is very similar to problem 22.

6. Imagine that an atomic bomb causes about 15 kg of U-235 to undergo fission. About how long did the chain reaction last? We'll answer the question in stages:

   (a) Assume that the multiplication factor is equal to 2. This means that a stray neutron induces one fission, which causes two fissions, which cause four fissions, and so on. About how many such doublings will it take before the entire 15 kg is consumed?

   (b) Argue that 99.9% of the energy is released in the last 10 doublings.

   (c) Estimate the speed of a neutron having 1 MeV of kinetic energy, which is about average for a fission neutron. (You do not need to make relativistic corrections, since the rest mass of the neutron is 939 MeV, much larger than its KE.)

   (d) About how long will it take such a neutron to travel the width of the uranium sphere, which will be about 10 cm across? This will roughly be the time between successive doublings. Explain why.

   (e) How long does the *entire* chain reaction take? Over what period is 99.9% of the energy released?

7. A few minutes after the Big Bang the first fusion reaction occurred in the early universe. It was $n + p \rightarrow d + \gamma$. Compute the Q for this reaction. (d stands for a deuterium nucleus.)

8. In a nuclear reactor, the *reproduction factor, k* is the increase in the number of neutrons producing fission in each generation, which is estimated by considering all the loss mechanisms for neutrons in the reactor assembly. In the bomb example above k was 2.

If the reproduction factor of a reactor is $k = 1.1$, find the number of generations needed for the power to (a) double, (b) increase by a factor of 10, and (c) increase by a factor of 100. Find the time needed in each case if (d) there are no delayed neutrons, so the time between generations is 1 ms, and (e) there are delayed neutrons (due to decay of fission fragments) that make the average time between generations 100 ms. (Hint: review your logarithms!)