Physics 736 - Exercises #1

1 Instructions

• Solutions are due on Monday, February 6, 2013. Please leave them in Karsten Heeger’s mailbox or bring them to class.

• Everyone is expected to write out their own solutions but discussions with your classmates are definitely encouraged. Consider it a research assignment.

• Exercises will be graded by Walter Pettus (email: pettus@wisc.edu). For questions contact Karsten Heeger (email: heeger@wisc.edu).

• Topics: radioactivity, basic nuclear processes, interaction of particles in matter

2 Questions

1. One gram of cobalt is placed near the core of a nuclear reactor where it is exposed to a neutron flux of $5 \times 10^{14}$ cm$^{-2}$s$^{-1}$. The cross-section for thermal neutron capture on $^{59}$Co is $\sim 40$ b. Calculate the $^{60}$Co activity after one week of irradiation.

2. Explain what is meant by secular equilibrium, and write out an equation for the condition of secular equilibrium.

3. The half-lives of $^{234}$U, $^{235}$U, and $^{238}$U are respectively $2.5 \times 10^5$ years, $7.1 \times 10^8$ years, and $4.5 \times 10^9$ years. Their relative natural abundances are respectively 0.0057%, 0.72%, and 99.27%. Are these data consistent with the assumption that these nuclei were formed in equal amounts at the same time? If not, can one explain the discrepancy knowing that the unstable isotopes $^{234}$Th and $^{234}$Pa exist? (Hint: Look at the decay chains...)

4. Exponential absorption of particles in matter takes the form $N(x) = N_0 e^{-\mu x}$. Show that the mean free path of a particle undergoing exponential absorption is given by $1/\mu$.

5. A radioactive source emits gamma rays of 1.1 MeV energy. The intensity of these gamma rays must be reduced by a factor $10^4$ by a lead container. How thick must the container walls be?

6. Show that pair production is not possible without the presence of a nucleus to take up momentum.

7. The transmission of charged particles through matter is dominated by atomic and not nuclear interactions.

   (a) What is the reason for this?

   (b) When is this no longer true, i.e. when do nuclear interactions become important?