Universität Leipzig, Fakultät für Physik und Geowissenschaften

Exercises for Experimental Physics 4 – IPSP

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Exercise Sheet 11 (Summer Term 2013)

Date of Issue to Students: June 25^{st} 2013

Date of Submission: July 2^{nd} 2013

Submission Place: Marked mailbox next to room 302 (Linnestr. 5)
Submission Time: 11:00 a.m. at the submission day noted above

Please note: Write your name and matriculation number on EACH sheet of paper.
Only submit the calculations and results for exercise 1-3, exercise 4 will be discussed during the instruction classes.

Exercises:

1. A sample of radioactive material is initially found to have an activity of 115.0 decays/min. After 4 d 5 h, its activity is measured to be 73.5 decays/min. (a) Calculate the half-life of the material. (b) How long (from the initial time) will it take for the sample to reach an activity of 10.0 decays/min? (7 Points)

2. Consider a single nucleus of a radioactive isotope that has a decay rate equal to λ. The nucleus has not decayed at $t = 0$. The probability that the nucleus will decay between time t and time $t + dt$ is equal to $\lambda e^{-\lambda t}\, dt$.
(a) Show that this statement is consistent with the fact that the probability is 1 that the nucleus will decay between $t = 0$ and $t = \infty$.
(b) Show that the expected lifetime of the nucleus τ is equal to $1/\lambda$. Hint: The expected lifetime is equal to $\int_0^\infty t\lambda e^{-\lambda t}\, dt$ divided by $\int_0^\infty \lambda e^{-\lambda t}\, dt$.
(c) A sample of material contains a significant number of these radioactive nuclei at time $t = 0$. What will have been the mean lifetime of these nuclei some time later, after they have all decayed? (9 Points)

3. The total energy consumed in the United States in 1 y is approximately $7.0 \cdot 10^{19}$ J. How many kilograms of ^{235}U would be needed to provide this amount of energy if we assume that 200 MeV of energy is released by each fissioning uranium nucleus, that all of the uranium atoms undergo fission, and that all of the energy-conversion mechanisms used are 100 percent efficient? (4 Points)

4. In 1920, 12 years before the discovery of the neutron, Ernest Rutherford argued that proton-electron pairs might exist in the confines of the nucleus in order to explain the mass number, A, being greater than the nuclear charge, Z. He also used this argument to account for the source of beta particles in radioactive decay. Rutherford's scattering experiments in 1910 showed that the nucleus had a diameter of approximately 10 fm. Using this nuclear diameter, the uncertainty principle, and that beta particles have an energy range of 0.02 MeV to 3.40 MeV, show why the hypothetical electrons cannot be confined to a region occupied by the nucleus.