B Homework exercises I

This set of exercises should be completed and submitted via **Brightspace** by **Wednesday 17th of January 2018** before 17h.

1) We have a sample of 1.49 μg of pure ${}^{13}_{7}$N, characterized by a half-life of $\tau = 600$ s.
Answer the following questions:
a) How many atoms are there in this sample of pure nitrogen?
b) How large is the activity at $t = 0$?
c) How large is the activity after one hour?
d) How much ${}^{13}_{7}$N do we still have after one hour?
e) Assume that ${}^{13}_{7}$N undergoes a beta decay of the form ${}^{13}_{7}\mathrm{N} \to \mathrm{X} + e^+ + \nu$. What is X here? Is this reaction actually possible?

2) Consider the radiative decay of polonium-210: ${}^{210}_{84}\mathrm{Po} \to \mathrm{X} + \alpha$.
a) What is X in this reaction, and why?
b) Determine the energy Q released in this decay (in MeV), using that $m_{\mathrm{Po}} = 209.93676$ u, $m_{\mathrm{X}} = 205.92945$ u, and $m_\alpha = 4.0012$ u.
c) Compute the kinetic energy that the α particle has in this decay process. Make use of the conservation of energy and momentum, and assume that the Po nuclei was at rest before decaying. Assume also Newtonian (non-relativistic) mechanics.
d) Compute the velocity of the radiated α particle. Should we worry about relativistic effects? Why?

3) What is the energy that we need to supply to a proton in order to accelerate it from $\beta = 0$ to $\beta = 0.9$? And from $\beta = 0.9$ to $\beta = 0.99$? And from $\beta = 0.99$ to $\beta = 0.999$? Is is possible to accelerate then the proton up to $\beta = 1$? Why?

4) An electron in a cathodic rays tube, starting from rest, experiences a potential difference of $\Delta V = 5 \times 10^4$ V between an initial position and a screen that can measure its position upon impact. With which speed does the electron reach the screen? Perform the calculation using both classical mechanics and relativistic mechanics. How do the results change if now the potential difference is increased up to $\Delta V = 2 \times 10^5$ V? And to $\Delta V = 10^6$ V? For which values of the potential difference is the classical approximation sensible and for which others one needs the relativistic expressions?

5) An unstable particle at rest, denoted by X, decays into two lighter particles A and B. We know that particle A has a mass of 6.67×10^{-27} kg and a speed of $\beta = 0.6$. We also know that particle B has a mass of 1.67×10^{-27} kg. Determine the speed of particle B. Compute also the mass of the initial particle X.

6) Consider an anti-proton, traveling with momentum 1 TeV/c in the z direction.
a) Assume that this anti-proton collides head-on with a proton carrying the same momentum but traveling in the opposite direction. Assume that the result of this collision is a new particle. Using energy-momentum conservation, compute the four-momentum of this new particle. What is its mass?
b) Same situation as above, but now with the proton standing at rest.
c) Discuss what are the advantages and advantages of the two configurations described above.