SELF-STUDY QUESTIONS

February 2010

Nuclear physics

1. Write down the semi-empirical mass formula (you do not have to give numerical values of constants) and give a motivation for the different terms.
2. Derive an expression for the β-stability line.
3. Discuss different types of instability in atomic nuclei. In which part of the nuclear chart are the different decay modes most important?
4. Describe different types of excitations in atomic nuclei.
5. Describe how electron capture works. Drawing a figure may be helpful.
6. In a star most atoms are fully ionized. Even so, electron capture is possible. Explain why.
7. Why do we have electron capture instead of β^+ decay in one of the pp-chains? Both processes would lead to the same final result.

Nuclear reactions

1. What is cross section? Describe schematically how the cross section can be expressed in terms of the Compton wavelength.
2. Derive an expression for the average number of reactions occurring per time and volume unit between two different kinds of particles, assuming thermal equilibrium. The expression shall contain an integral over the relative velocity.
3. Rewrite the expression such that we integrate over the energy instead. Notice that the relative velocity has a Maxwell-Boltzmann distribution:

$$\Phi(v)\ d^3v = 4\pi v^2 \left(\frac{\mu}{2\pi kT}\right) e^{-\mu v^2/2kT} dv$$

4. Derive an expression for the number of nuclear reactions in stars when the energy is close to a resonance in the cross section.
5. Give an example of an important process in which a resonance plays a key role.
6. Write down and motivate an expression for the non-resonance cross section for thermal reactions between two atomic nuclei with Z_1 (N_1) and Z_2 (N_2) protons (neutrons) respectively.
7. Show how the maximum of the cross section is shifted away from that of the Maxwell-Boltzmann distribution
8. Show that the number of fusions (per time and volume unit) of heavier atomic nuclei (e.g. $\alpha\ +\ {}^{16}\mathrm{O}$) in a star has a much stronger temperature dependence than the number of fusions of e.g. two protons.

Elementary particle physics

1. What are leptons, hadrons, mesons and baryons?
2. Name the known and expected quarks and leptons and place them in families. What is the charge of the different particles? What spin do they have?
3. What is "flavor" and "color"?
4. Give a motivation to the introduction of the notation "color".
5. Which kinds of force mediating particles exists according to the standard model?
6. Describe the β^- decay at the quark level using Feynman diagrams.