Proposals for theory talks

1. *Title*: **Exchange interaction**

Task: The exchange interaction is a purely quantum-mechanical effect which may significantly affect the energy spectrum of a system of two (or more) indistinguishable particles. For example, it removes (in the first order) the degeneracy between singlet and triplet states of the neutral helium. In this talk, one needs to use the perturbation theory and the model of independent electrons in order to calculate energies of excited helium states and to illustrate the role of the exchange interaction.

Literature: [1] B. H. Bransden and C. J. Joachain, "*Physics of atoms and molecules*".
[2] H. Bethe and E. Salpeter, "*Quantum Mechanics of One- and Two-Electron Atoms*"

2. *Title*: **Geonium atom**

Task: Geonium is an artificial atom which consists of a single electron confined inside a Penning trap. Since its invention by Hans Dehmelt and co-workers, this "atom" plays an important role in high-precision measurements of the g-factor. In this presentation, one will present the basic theory of the geonium with the special attention on the electron's motion in the Penning trap as well as on the Hamiltonian and energy spectrum of the system.

Literature: [1] D. Budker, D. F. Kimball, and D. P. DeMille, "*Atomic Physics. An exploration through problems and solutions*". [2] L. S. Brown and G. Gabrielse, Reviews of Modern Physics **58**, 233 (1986).

3. *Title:* **Atomic parity violation effects: Non-relativistic model**

Task: The neutral weak interaction between the electron cloud and the nucleus, mediated by a neutral Z^0 boson, may lead to a mixing of atomic levels of opposite parity. Such a mixing, being a clear manifestation of the atomic parity violation (APV), attracts nowadays much interest both in experiment and theory. In order to illustrate the main features of the APV phenomena, one will consider a simplified picture of a weak interaction in the non-relativistic framework. Within this framework and by employing the first-order perturbation theory, one can easily demonstrate that the weak-interaction Hamiltonian really violates parity and to estimate Z-scaling of the PV effects for the case of valence s- and p-electrons.

Literature: [1] D. Budker, D. F. Kimball, and D. P. DeMille, "*Atomic Physics. An exploration through problems and solutions*". [2] M.A. Bouchiat and C. Bouchiat, Reports on Progress in Physics **60**, 1351 (1997).

4. *Title:* **Permanent Electric Dipole Moment (EDM) of charged particles**
   Task: Together with the studies of the atomic parity violating, search for a permanent electric dipole moment of charged particles (proton, deuteron and heavy ions) provides an important route towards testing the Standard Model. In the proposed presentation, one is required to make a short overview of the theoretical background of EDM studies. In particular, one shall explain why EDM breaks both P- and T-symmetry, relate such a violation to the general CPT-theorem, and briefly sketch EDM-measurement schemes.

   Literature: [1] http://budker.berkeley.edu/Searches%20for%20EDM.pdf . [2] http://g2pc1.bu.edu/leptonmom/talks/fortsonhg.pdf . [3] I. B. Khriplovich, and S.K. Lamoreaux, "*CP Violation without Strangeness: Electric Dipole Moments of Particles, Atoms, and Molecules*" (Springer-Verlag, Berlin, 1997)

5. *Title:* **Hyperfine quenching of excited ionic states**
   Task: For the nucleus with a non-zero spin, $I \neq 0$, its magnetic interaction with the moving electron(s) of the atom leads to the so-called hyperfine effects. Apart from the splitting of atomic energy levels, dependent on the mutual orientation of nuclear and electron spins, hyperfine interactions result also in a mixing of states of different momenta J. Such a mixing plays a very important role for the precise spectroscopy of excited ionic (atomic) states. In order to illustrate the effect of the hyperfine quenching one might consider the simplest case of the mixing between $P_{1/2}$ and $P_{3/2}$ states.

   Literature: [1] D. Budker, D. F. Kimball, and D. P. DeMille, "*Atomic Physics. An exploration through problems and solutions*".

6. *Title:* **Two-photon atomic decay**
   Task: Radiative transitions between atomic states may proceed via simultaneous emission of two gamma quanta. These (two-photon) transitions play important role especially if single-photon decays are forbidden by parity or momenta selection rules. In this talk, one shall review the theoretical background of two-photon studies, as provided by the second-order perturbation theory, and discuss the basic properties of emitted photons such as their energy distribution. As an example, one might consider $2s \rightarrow$ 1s or $1s\,2s\,S_0 \rightarrow 1s^2\,S_0$ transitions in hydrogen- and helium-like ions, correspondingly.

   Literature: [1] http://www.scribd.com/doc/53137825/54/Two-photon-decay-of-the-2s-state-of-Hydrogen . [2] http://www.phy.anl.gov/atomic/PUBS/camop31.pdf [3] S. Trotsenko et al., PRL **104**, 033001 (2010).