Questions on 'Nuclear Structure Theory (FMF121,FYST11)', 2015.

1. Sketch the charge distribution in nuclei. Define the root-mean-square radius. Give typical values for radius and diffuseness. A-dependence? Exemplify methods to measure the charge distribution.

2. Discuss the different terms in the semi-empirical mass formula. Which is the role of the pairing energy? Indicate typical errors when this formula is used to describe experimental masses. Which nuclei will gain energy when undergoing fission and fusion, respectively (cf. Fig. 3.6)?

3. Define the β-stability line and the proton and neutron drip lines. Sketch the stability peninsula. Estimate the number of β-stable nuclei for a fixed mass number, A. Are there any typical differences between odd and even A (cf. Figs. 3.4, 3.5)?

4. Sketch a typical fission barrier. Which nuclei decay through spontaneous fission? Which terms in the liquid drop model are important for the height of the fission barrier? Discuss typical numerical values of the fission barrier and the energy gain in fission!

5. Define the isospin! Which isospin states are possible for a two-nucleon system? How can isospin be used to define a generalized exclusion principle?

6. Discuss some invariance properties for the nucleon-nucleon interaction. How can the most general central static nucleon-nucleon potential be written? Sketch the r-dependence.

7. Which is the most important velocity-dependent force in the nucleon-nucleon interaction?

8. Explain how a different order of the subshells (the j-shells) leads to different magic numbers for the electron system compared with the proton or neutron system.

9. Write down the Hamiltonian in the Hartree approximation for the atomic electron system. How is the total wave-function written in terms of the single-electron wave-functions?

10. Which is the basic difference between the Hartree and the Hartree-Fock method? Which is the form of the total wave-function in the Hartree-Fock approximation?

11. Explain the difference between a central potential $V(r)$ and the corresponding effective potential V_{eff}.

12. Consider a spherically symmetric harmonic oscillator potential. Which is the energy spectrum expressed in the quantum numbers N and (n, l), respectively? Which values of l are allowed for fixed N?

13. Which are the preserved quantum numbers of a spin 1/2 particle in a spherical symmetrical potential, $V(r)$? Which is the general dependence of the radial wave-function on the quantum numbers n and l?

14. Which is the role of the spin-orbit potential? Which are the preserved quantum numbers of a spin 1/2 particle in a spherical potential well in the presence of a spin-orbit potential?

15. Compare the modified oscillator potential and some other 'realistic' nuclear single-particle potential. How is the value of the $\hbar\omega_0$ parameter determined in the modified oscillator potential?

16. Give a general definition of Clebsch-Gordan coefficients. Which are the preserved quantum numbers in the wave-functions which enter in the definition? In which range do these quantum numbers vary?

17. Discuss briefly the symmetry relations of the Clebsch-Gordan coefficients (you only need to remember the general structure of the formulas)! Give one example when the addition theorem is useful.

18. What is the quadrupole moment a measure of? Explain the polarization effect!

19. Compare the g-factors for a free nucleon and for a nucleon in a nucleus. How is the magnetic moment calculated?

20. Define the Schmidt values of the magnetic moment!

21. Explain Fig. 8.1!

22. Which matrix element determines the splitting of a j-shell at a small quadrupole deformation? Which Ω-values come lowest in energy at prolate shape?

23. What is meant by asymptotic quantum numbers? They are generally written as $|Nn_z\Lambda\Omega\rangle$. Which of these quantum numbers are exact and which are approximate in the eigenfunctions of the modified oscillator Hamiltonian? Describe a method to find all possible vales of n_z, Λ and Ω for a fixed N.

24. Why volume conservation? Which is the volume conservation condition for a triaxial harmonic oscillator?

25. When solving the axially symmetric harmonic oscillator Hamiltonian, one introduces the operators R and S (and $R^\dagger$, $S^\dagger$). Which Cartesian directions are involved in these definitions? Write down the number operator using these operators.

26. Sketch possible shapes for a nucleus with ε_2- and ε_4-deformation! Which range of γ-values are needed to describe all triaxial shapes?

27. Which is the main reason to introduce stretched coordinates?

28. Which is the main idea of the shell correction method? Explain Fig. 9.1.

29. Explain qualitatively how an appreciable fission barrier might be formed in a superheavy nucleus with a very small or vanishing liquid drop fission barrier (cf. Fig. 10.6).

30. Discuss the depth of the potential well for protons and neutrons in nuclei close to the proton and neutron drip line. Give typical values for the binding energy of the last bound proton and neutron for such nuclei! Consequences?

31. Rewrite the rotor Hamiltonian to demonstrate the appearance of deformation aligned and rotation aligned spectra, respectively. Which is the I-dependence of the energy in the two cases?

32. Which features favour deformation alignment and rotation alignment, respectively?

33. Explain Fig. 11.4.

34. Which term in the Hamiltonian gives rise to the decoupling parameter? Which kind of rotational bands are affected by the decoupling parameter?

35. Describe the cranking model. What does the Hamiltonian look like?

36. Which equilibrium shapes are possible at different values of the angular momentum in the rotating liquid drop model?

37. Describe how the ground band of ^{20}Ne develops towards termination. How does the shape change? Which is the terminating spin value?

38. Consider the nucleus ^{157}Er with $Z = 68$ and $N = 89$. At which spin values would you expect to observe terminating states? (you might consult a diagram like Fig. 6.3 (or Fig. 8.3 or Figs. 11.3,4) if you do not remember the order of the j-shells) How is it possible to build higher spin values (the terminating states were discovered in the nineties but it was first after year 2000 that higher spin states were observed).

39. Which is the difference between a δ-force and a pairing force for two identical particles in a j-shell?

40. Define the anticommutator relations for the creation and annihilation operators. Which is the form of a general two-particle operator using these operators? How can the pairing force be written?

41. Write down the Hamiltonian for particles in two-fold degenerate orbitals which are subject to a pairing force.

42. Which two methods can be used to find approximate solutions of the Hamiltonian for particles in two-fold degenerate orbitals which are subject to a pairing force (you are not expected to remember the details). Which is the physical significance of the V_ν and U_ν coefficients?

43. Explain Fig. 14.5

Do not forget the *Hand-in problems* and the *Computer project*!