Lunds universitet, Fysiska institutionen, Avdelningen för synkrotronljusfysik
Spektroskopi och materiens kvantmekaniska beskrivning FYST20, vårterminen 2012

Light - matter interaction (up to Fermi's Golden Rule)
Questions for your discussion

1. Why do you think $\nabla \boldsymbol{A} = 0$ is called the transversality condition?
2. Why can't the Lagrangian of the free particle (electron) L_{free} depend on the position?
3. What is the difference between the mechanical momentum and the conjugate momentum?
4. ** What does the electric dipole approximation imply physically? For which photon energies is it valid?
5. Why can one skip the last term in Eq. (1.51) if the light intensity is sufficiently low?
6. ** Explain in your own words Why $\langle f|H|i\rangle$ describes a quantum mechanical transition.
7. Apart from electric dipole transitions also higher order transitions might occur. What will be the most pronounced spectroscopic difference of these transitions as compared to dipole transitions? Take a lithium atom as an example and draw a scheme for transitions in the lithium atom irradiated by monochromatic light in an energy range appropriate for discrete transitions. Which of these transitions do you expect to be observed in reality, which are weaker and which are stronger?
8. ** Why does one treat the transitions occurring in an XPS or XAS experiment in the perturbation limit, i.e., why can one apply Fermi's Golden Rule?
9. We have said that a quantum mechanical transition can be described by the matrix element $\langle f|H|i\rangle$ (why is it called matrix element?). What is the difference of this matrix element and that contained in Fermi's Golden Rule in Eq. (1.113)?
10. ** What does the second term in Fermi's Golden Rule in Eq. (1.113) imply?
11. ** Give examples for continuum states as final states of Fermi's Golden Rule.
12. What is - in your opinion - the crucial simplification step in the derivation of Fermi's Golden Rule?

13. For discrete initial and final states and resonant excitation, plot P_{if} as a function of time. What happens physically?

14. For discrete initial and final states and resonant excitation, plot P_{if} as a function of photon energy (i.e., for a certain time t). What does this mean?

15. In the compendium it was written that β, e.g., could be the crystal momentum. Can you think of any other possibilities? What is the crystal momentum and what is the different to the "normal" momentum?

16. Fermi's Golden Rule is often written as follows: $w = \frac{2\pi}{\hbar} |M_{fi}|^2 \delta (E_f - E_i)$. What is the difference to the formulation in the compendium?