Name: ____________________________

Advanced Solid State Physics — Prof. Dr. W. Kuch
Winter semester 2014/2015
10th exercise sheet

Submission: Tuesday, 06. January 2015, before the lecture
(or drop until 10 o'clock of the same day in mailbox between rooms 1.2.38 and 1.2.40)

27. Photoemission with high kinetic energies (*) (4 points)
Calculate the angle resolution of the electron detector that is necessary to obtain a resolution in $k_{\|}$ in angle-resolved photoemission of 1% of the Brillouin zone (1/100 of the distance between Γ and X) in [100] direction of Ni (fcc, a = 3.52 Å) in the two cases described under a) and b). Assume 4.5 eV as work function of sample and detector and consider states close to the Fermi energy for near-normal emission.

a) Photon energy $\hbar\omega = 21.2$ eV (He-I UV lamp),
b) photon energy $\hbar\omega = 1253.6$ eV (Mg-K_α X-ray tube).

28. Spin-resolved photoemission (**) (4 points)
In a spin-resolving electron analyser, an incoming electron with spin down is scattered at a solid and reaches with a probability $T\,r$ the right detector, with a probability $T(1–r)$ the left detector ($1/2 \le r \le 1$), and is lost with a probability $1–T$. (Typical values: $T \approx 10^{-3}$, $r \approx 0.65$.) Electrons with spin up scatter oppositely.

a) Calculate the asymmetry A_{Sherman} of the detector output signals $(I_{\text{left}}–I_{\text{right}})/(I_{\text{left}}+I_{\text{right}})$ for a fully spin-polarized input signal (only electrons with spin up are entering the spin detector).
b) Which asymmetry A of the two detector output signals is measured if the input signal has a spin polarization P_0 defined as $P_0 = (I_\uparrow - I_\downarrow)/(I_\uparrow + I_\downarrow)$, where $I_\uparrow + I_\downarrow$ is the total input current of electrons?
b) Express the input currents of spin up and spin down electrons $I_\uparrow$ and $I_\downarrow$ as functions of the measured detector signals I_{left} and I_{right}, assuming that A_{Sherman} and T are known.

29. Quantum well states (**) (4 points)
We want to look at quantum well states of nearly free electrons in an ultrathin film with fcc lattice and (001) surface orientation. To simplify, we consider phase jumps of π upon reflection of the electronic wave function at both interfaces, like in an infinitely high potential well.

a) Calculate the Fermi wave vector k_F for free electrons in three dimensions under the assumption of N_{el} = 1.3 electrons per atom.
b) Calculate the thickness period (in atomic monolayers) at which quantum well state peaks shift across the Fermi level upon increasing the film thickness. The width of the quantum well is $d = \nu a/2$, with a being the lattice constant of the fcc crystal, and ν an integer number (film thickness in units of atomic monolayers). Make sure to take into account the larger period due to the discrete thickness values of such films compared to a quantum well with continuously increasing width if **k** is in the second half of the Brillouin zone.