Name: ____________________________

Advanced Solid State Physics
Winter semester 2014/2015
12th exercise sheet

Prof. Dr. W. Kuch

Submission: Tuesday, 20. January 2015, before the lecture
(or drop until 10 o'clock on the same day in mailbox between rooms 1.2.38 and 1.2.40)

33. Mean-field theory (**) (4 points)
In the mean-field approximation of ferromagnetism the interaction between neighboring atomic magnetic moments is treated by substituting the external magnetic field H by an effective field $H + \lambda M$. Starting from non-interacting paramagnetic moments, execute this substitution in the argument of the Langevin function. The result is a transcendental equation in M.

a) Show graphically that for H = 0 solutions with $M \neq 0$ exist in a certain temperature range. To do so, plot both sides of the transcendental equation as $M(\alpha)$ versus α, where $\alpha = \dfrac{\mu_0 \mu_{at}(H + \lambda M)}{k_B T}$.
b) Determine from the initial slope of the Langevin function the maximum temperature T_C for which at H = 0 a non-vanishing solution for M exists.
c) Estimate then for iron with $T_C = 1063$ K, $\mu_{at} = 2.2\ \mu_B$, and $\rho_{at} = 8.54 \cdot 10^{28}\ m^{-3}$ the mean-field parameter λ.
d) What is the corresponding effective magnetic field λM at T = 0?

34. Magnetic shape anisotropy of thin films (*) (4 points)
a) Calculate the value of the external magnetic field applied along the surface normal which is necessary to pull the magnetization of the following thin film to within 10° from the surface normal: Film thickness 1.0 nm, saturation magnetization $M_S = 1.72 \cdot 10^6\ \frac{A}{m}$ (for example Fe), negligible magneto-crystalline anisotropy.
b) Sketch the magnetization curve $M_\perp(H_\perp)$ which is measured along the surface normal.

35. Expansion of the angle dependence of magneto-crystalline anisotropy (**) (4 points)
Show that the following two representations of the angle dependence of the magneto-crystalline anisotropy within a plane (for example the film plane if the sample is a thin film) are equivalent. The angle φ defines the magnetization direction within this plane.

$E_{anis} = K_1 \cos^2\varphi + K_2 \cos^4\varphi$ and
$\tilde{E}_{anis} = \tilde{K}_1 \cos(2\varphi) + \tilde{K}_2 \cos(4\varphi)$.

Determine the relation between K_1, K_2 and $\tilde{K}_1, \tilde{K}_2$. Sketch the anisotropy energy as a function of the angle φ for $K_1 > 0, K_2 = -2K_1$.