Name: ____________________________

Advanced Solid State Physics
Winter semester 2014/2015
13th exercise sheet

Prof. Dr. W. Kuch

Submission: Tuesday, 27. 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)

36. Micromagnetism: Exchange energy in one dimension (**) (6 points)

We consider a one-dimensional chain of identical atoms with nearest-neighbor distance a, the atomic magnetic moments $\vec{s}_i$ of which can be oriented in three dimensions ("1-D Heisenberg model", $|\vec{s}_i| = S = \text{const}$). The exchange energy of this system in the Heisenberg model is given by $E_{exch} = -J\sum_i \vec{s}_i \cdot \vec{s}_{i+1}$, where we consider exchange coupling only between nearest neighbors. In most cases the direction of the atomic magnetic moments will vary only very little between nearest neighbors, such that a continuum approximation may be used.

Show that the equation $E_{exch} = A\int_{-\infty}^{+\infty} dx\left\{\left(\frac{ds_x}{dx}\right)^2 + \left(\frac{ds_y}{dx}\right)^2 + \left(\frac{ds_z}{dx}\right)^2\right\} + \text{const}$ describes the exchange energy in the continuum approximation and derive the relation between the exchange constant A and the exchange coupling parameter J.

Hint: Start from the equation for the continuum approximation and discretize it into atomic distances ($dx \rightarrow a$).

37. Stoner-Wohlfarth model (***) (6 points)

In the Stoner-Wohlfarth model it is assumed that during magnetization reversal the magnetization of the entire sample behaves like one single macrospin, i.e., that all atomic magnetic moments are always aligned in parallel. (This is approximately the case in nanostructures.) The direction of magnetization can then be calculated by tracing the local minimum of the total energy.

Calculate the coercive field H_C in the Stoner-Wohlfarth model that is necessary to reverse the magnetization of the following sample: Thin film, magnetization M is always in the film plane, the direction of M is defined by the angle φ, the magnetic anisotropy can be described by $E_{anis} = K_1 \cos^2\varphi + K_2 \cos^4\varphi$ with $K_1 > 0$ and $K_2 = -2K_1$, like in exercise 35. We start with $\varphi = 0$. The external magnetic field H is applied opposite to that direction, i.e., favoring a magnetization direction described by $\varphi = \pi$. „Magnetization reversal" means that after switching off the external field the magnetization M remains along $\varphi = \pi$.

Hint: Sketch the total energy of the system for different values of H. Determine then the position of the extrema, or solve the resulting equation graphically.