ECE 18-316
INTRO TO DATA STORAGE
FALL 98
PROBLEM SET #5

Due Friday, 10/2/98

In Class or To Jie Zou Before Start of Lab Section (1:30 PM)
Late submissions will not get credit

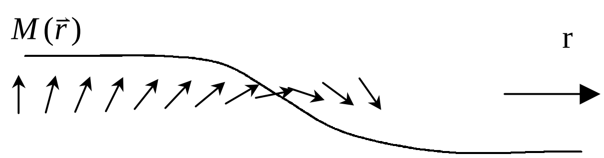
1. In class we stated that the exchange between two spins had the form:

$$E_{ex} = -2J\vec{S}_1 \cdot \vec{S}_2$$

If the angle, θ, between spins is small, this angular dependence becomes (convince yourself of this by doing a small angle expansion of the dot product)

$$E_{ex} = JS^2\theta^2$$

Suppose the magnetization, $M(\vec{r})$, varies gradually across many spins:



The total angle associated with a change ΔM_x over a distance Δx is then $\Delta x/M$. If the distance between spins is d, then the angle, θ, between spins is

$$\theta = \frac{\Delta M_x / M_s}{\Delta x / d}$$

A more general argument gives

$$\theta = \frac{\left|\nabla \vec{M}\right| d}{M_s} \qquad \text{where} \qquad \left|\nabla \vec{M}\right|^2 \equiv (\nabla M_x)^2 + (\nabla M_y)^2 + (\nabla M_z)^2$$

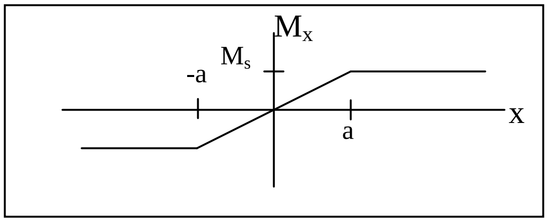
If each spin has z neighbors in the direction of the changing magnetization, and the atomic volume is, Ω, the exchange energy density becomes:

$$e_{ex} = A\frac{\left|\nabla \vec{M}\right|^2 d}{M_s^2} \qquad \text{where} \qquad A = \frac{zd^2JS^2}{\Omega}$$

a) Using the parameters for fcc iron given in class and the previous homework, and an exchange value of 12 meV, calculate the value of A. (note meV is milli-eV, and you may have to convert this value to different units). For the purposes of calculation and estimating z, assume the x-direction is parallel to the (100) direction of the crystal.

b) Suppose we had a magnetization which had the form:

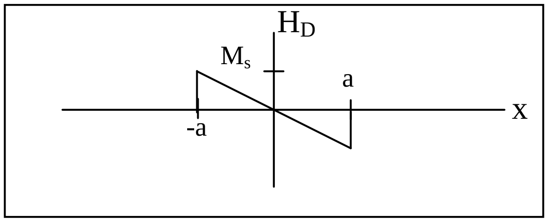
$$\vec{M} = M_x \hat{x} = \begin{cases} -M_s & x < -a \\ M_s \dfrac{x}{a} & -a \le x \le a \\ M_s & x > a \end{cases}$$



calculate the exchange energy by integrating along the x-axis (i.e. assume a unit length in the y and z directions)

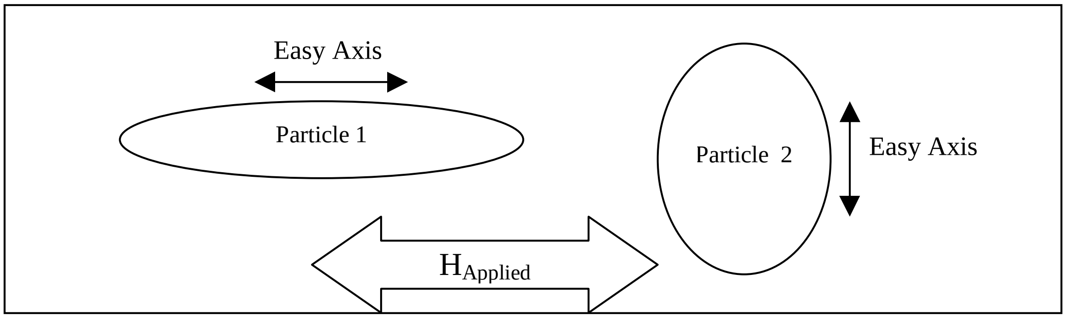
c) Assuming the demagnetizing field associated with this magnetization is

$$\vec{H}_D = H_{D,x} \hat{x} = \begin{cases} 0 & x < -a \\ -M_s \dfrac{x}{a} & -a \le x \le a \\ 0 & x > a \end{cases}$$



d) Plot the ratio of the exchange energy to the demagnetizing energy as a function of a, for a varying from d for fcc Fe to 10 um. Use log axes.

2) Consider a powdered magnetic sample consisting of two types of particles, differing in their orientation and shape, and having the same saturation magnetization. These particles are elongated ellipsoids. As discussed in class, their shape causes the major axis of these ellipsoidal particles to become a magnetic easy axis. The characteristics of particles 1 and 2 are tabulated below, and their orientation relative to an applied field is shown in the figure.



	Particle 1	Particle 2
N (in Easy Axis Direction) [unitless]	0.1667	0.2
Ms (A/m)	10^6	10^6
Orientation of Easy Axis relative to applied field	0°	90°

a) Plot the hysteresis loop as a function of applied field for each of these particles on the same graph. Label the axes quantitatively. You will be aided in this task by the chart in your class notes that shows the switching process of particles for various orientation and fields. Note that this chart is in units that are normalized to H_k and Ms. On your plot, do NOT normalize these quantities. The axes should be in units of M (A/m) (vertical axis) and H (A/m) (horizontal axis).

b) If both types of particles were present in the sample in equal amounts, and we could simply add their responses together, what would the remanent (i.e. zero applied field) magnetization of the sample be? (Assume that the particles occupy 100% of the volume of the sample, so that you can simply take an average of the magnetization at each field value). What would the coercivity be? (i.e. the value of H at which the magnetization crosses the zero axis).