MAT 204, Spring 2009. Homework 4.

Due in class on Wednesday May 6th.

QUESTION 1

(a) Why do domains form in ferromagnetic materials? What are the various contributions to the total energy of a ferromagnetic material, and how do they determine the size and shape of domains.

(b) Sketch and explain how the domain structure changes during magnetization of an initially unmagnetized sample of ferromagnetic material to saturation.

(c) What characteristics would you expect in the magnetization curve and hysteresis loop of a ferromagnetic material which has many defects? Suggest an application for such a material.

(d) What characteristics would you expect in the hysteresis loop of a ferromagnetic particle with average magnetocrystalline anisotropy, which is so small that it consists of a single domain. Again, suggest an application.

(e) The exchange energy cost per square meter, σ_{ex}, within a domain wall is given by

$$\sigma_{ex} = \frac{kT_c}{2}\left(\frac{\pi}{N}\right)^2 N\frac{1}{a^2}\ \mathrm{Jm}^{-2},$$

where $N+1$ is the number of atomic layers in the wall, T_c is the ferromagnetic Curie temperature, and a is the spacing between the atoms. Similarly, the anisotropy energy cost per square meter, σ_A, is given by

$$\sigma_A = KNa\ \mathrm{Jm}^{-2}$$

where K, is the magnetocrystalline anisotropy constant. Assuming that these are the only two terms that contribute to the domain wall energy, calculate the energy per square meter of a domain wall in iron, in which $K = 0.5 \times 10^5 \mathrm{Jm}^{-3}$, $a = 0.3\mathrm{nm}$, and $T_c = 1014°\mathrm{C}$.

(f) The magnetostatic energy per unit volume of a spherical sample that is uniformly magnetized is given by

$$E = \frac{\mu_0}{6}M_s^2$$

where M_s is the saturation magnetization. Calculate the magnetostatic energy per cubic meter in a single domain sphere of iron, for which the saturation magnetization, $M_s = 1.71 \times 10^6$ A/m.

(g) Use your answers to parts (e) and (f) to estimate the critical size below which the lowest energy state of an iron particle consists of a single domain with no domain walls. More about this later!!