Magnetics

1. Consider a single domain particle with uniaxial magnetic anisotropy:

    a. Derive an expression for its energy barrier, and the M vs H easy and hard axis assuming magnetocrystalline anisotropy is the only contribution to the anisotropy. Plot and label relevant points for the easy and hard axis loops. [0.5 points]
    b. Write down the relaxation time equation for a single domain magnetic nanoparticles with energy barrier ΔE, attempt frequency f_0, and Boltzmann constant k_B and absolute temperature T. [0.5 points]
    c. Use your work in (a) and (b), derive a general expression for the coercivity of the particle as a function of time and temperature. [0.5 points]
    d. Other than magnetocrystalline anisotropy associated with a perfect bulk crystal, describe two other forms of anisotropy, and give an example how each may be formed in a real device. [0.5 points]
    e. Compare the coercivity (coercive force) along easy axis qualitatively between such a single domain particle and a group of such nanoparticles with magnetostatic interaction. Here assume the shape anisotropy is dominant. Explain the effect of the packing density on the coercivity. [0.5 points]

2. The initial discovery of giant magnetoresistance (GMR) was demonstrated using Fe/Cr multilayers. Answer the following related questions:

    a. What quantum mechanical effect is responsible for coupling between magnetic layers with the Cr non-magnetic spacer in such GMR stack? Sketch the dependence of the coupling vs the non-magnetic spacer thickness, explain what the plot means and how it can be used for device structures. [0.5 points]
    b. For a device with proper non-magnetic spacer thicknesses, calculate resistance change (ΔR) for $[Fe/Cr]_3$ using a two-resistor model with R_p (parallel) and R_{AP}(anti-parallel). Plot ΔR/R(H=0) vs H for such a device. [0.5 points]
    c. Lateral spin valve (LSV) is a GMR device with two magnetic layers connected through a non-magnetic channel in a lateral geometry. This geometry could enable the integration of magnetic materials with spin channels for spintronic logic applications. A ferromagnetic-semiconductor interface will be formed (F/SC) for such a device if using a semiconductor layer as the spin channel. Explain why a simple F/SC contact is not suitable for LSV devices, and list the solution to overcome this. [0.5 points]