PHY3129 Device Physics –Magnetic Device Problems

1. The coating on a magnetic disk drive consists of an assembly of weakly interacting magnetic particles with uniaxial anisotropy. Assuming that the uniaxial axes are well aligned with the direction of the applied field, use the Stoner-Wohlfarth model to calculate the switching field when the particles have magnetization of 480 kA/m and anisotropy constant of 6×10^5 J/m^3. Estimate the time for which written data would be stable if the grains have diameter of 6 nm. What diameter would be required for the data to be stable for 10 years?

2. A magnetic tunnel junction (MTJ) is formed from a Co free layer, a second exchange biased Co layer, and an aluminum oxide spacer layer. If the tunnel magnetoresistance ratio is measured to be 65%, calculate the spin polarization of Co at the Fermi level and hence the ratio of the spin-up and spin-down density of states at the Fermi level. What strategies might be employed to further increase the TMR?

3. A NiFe/Cu/Co/IrMn spin-valve sensor has Giant Magnetoresistance of 8%. The free layer has negligible magnetic anisotropy and has its magnetization biased at 90° to the fixed layer magnetization by a magnetic field of 1 kA/m supplied by surrounding permanent magnets ("hard bias"). Calculate the resulting sensitivity of the device.

4. Electrons are passed perpendicular to the plane of a spin-valve device of nanoscale diameter. If the fixed and free layers have magnetizations $\mathbf{M}_1$ and $\mathbf{M}_2$ respectively, show that the spin transfer torque acting on the free layer magnetization has the form $\mathbf{M}_2 \times (\mathbf{M}_2 \times \mathbf{M}_1)$. Explain the assumptions that you make. The equation of motion of the free layer may be written as

$$\frac{1}{|\gamma|}\frac{\partial \mathbf{M}_2}{\partial t} = -\mathbf{M}_2 \times \mathbf{B}_{eff} - \frac{\alpha}{M_2}\mathbf{M}_2 \times \left(\mathbf{M}_2 \times \mathbf{B}_{eff}\right) - \frac{g\mu_B J}{2|\gamma||e|M_2{}^2 d_2}\mathbf{M}_2 \times \left(\mathbf{M}_2 \times \hat{\mathbf{M}}_1\right).$$

For a specific device, the free layer magnetization, thickness and damping parameter have values of $M_s = 500$ kA/m, $d_2 = 2$ nm, and $\alpha = 0.01$. If an external field of 1 kA/m is applied to magnetize the free layer parallel to the fixed layer, estimate the current density required to induce spin transfer torque driven motion of the free layer magnetization.