ECS 521/641: Spintronics and Nanomagnetics

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HW #4

Problem 1

Determine the effective magnetic field due to shape anisotropy of a nanomagnet with in-plane magnetization and derive the full expressions of $d\theta/dt$ and $d\phi/dt$ with incorporating the magnetic field.

Problem 2

Consider an in-plane nanomagnet of shape as elliptical cylinder with dimension $(a, b, t) = (150\ nm, 100\ nm, 2\ nm)$ in the (z, y, x) direction.

Use $M_s = 8 \times 10^5 A/m$ and demagnetization factor $\left(N_{d-xx}, N_{d-yy}, N_{d-zz}\right) = (0.9468, 0.0339, 0.0193)$.

(a) Draw the potential landscape of the nanomagnet with respect to (θ, ϕ). What is the energy barrier?

(b) Draw the in-plane potential landscapes with the application of magnetic field in the *y*-direction $H_y = (0{,}0.2{,}0.5{,}0.7{,}1{,}1.4)H_k$. Plot how θ_{min} varies with H_y/H_k, and compare with the analytical calculations.

(c) Draw the in-plane potential landscapes with the application of magnetic field in the *z*-direction $H_z = (0{,}0.2{,}0.5{,}0.7{,}1{,}1.4)H_k$.

(d) Plot the magnetization dynamics for the following cases by numerically solving the Landau-Lifshitz-Gilbert equation using finite difference method with damping $\alpha = 0.01$ and 0.1. Determine the switching delay and energy dissipation due to damping. Compare the switching delay and energy dissipation for the cases of two damping parameters.
   a. Use $H_y = 2H_k$ and initial point $\theta \cong 180^o$.
   b. Use $H_z = 2H_k$ and initial point $\theta \cong 180^o$.

(e) Apply H_y and H_z together as shown in a presentation slide for magnetization switching and plot the magnetization dynamics. Choose the relevant values.

Problem 3

Consider a nanomagnet with perpendicular anisotropy of shape as elliptical cylinder and dimension $(a, b, t) = (20\ nm, 20\ nm, 5\ nm)$ in the (x, y, z) direction. Use $M_s = 4.8 \times 10^5 A/m$ and $H_{PMA} = M_s$.

Derive the analytical expression for switching delay with *z*-directed magnetic field. Use the expression later to match the numerical results.

Plot the magnetization dynamics by numerically solving the Landau-Lifshitz-Gilbert equation using finite difference method with damping 0.1. Determine the switching delay and energy dissipation due to damping. Use $H_z = 2H_k$ and initial point $\theta \cong 180^o$.