ECS 521/641: Spintronics and Nanomagnetics

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HW #9

Problem 1

Prove the following equality, which we have used during the derivation of spin Hall effect (2-DEG with no external magnetic field and no Dresselhaus interaction)

$$\frac{v_x^{\pm}}{v^{\pm}} = \frac{k_x}{k}.$$

Problem 2

Show that the following equation is correct even in the presence of spin-orbit interaction

$$\frac{d(\hbar k_x)}{dt} = -eE_x.$$

Show also that

$$\frac{dv_x}{dt} = -\frac{eE_x}{m^*}.$$

Hint: Use Ehrenfest theorem.

Problem 3

Use spin-transfer-torque to switch the magnetization of a single-domain nanomagnet. Consider the following two cases of in-plane and perpendicular anisotropy. Increase the current to a critical value at which the magnetization starts to switch. Also, use a current that is twice of the critical value. Plot the magnetization dynamics in 3D space. Determine the switching delay and energy dissipation due to magnetization damping α.

(a) 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 $M_s = 8 \times 10^5 A/m, \alpha = 0.01$, spin polarization $\eta = 0.6$, demagnetization factor $\left(N_{d-xx}, N_{d-yy}, N_{d-zz}\right) = (0.9468, 0.0339, 0.0193)$.

(b) 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 $M_s = 4.8 \times 10^5 A/m, \alpha = 0.1$, spin polarization $\eta = 0.6$, and $H_{PMA} = M_s$.