

*Problem* 12. Magnetic Materials

- A. Write the moment/atom in  $\mu_B$  of free iron atoms and  $\text{Fe}^{2+}$  ions in magnetic  $\text{Fe}_3\text{O}_4$ . Fe has atomic number 26 and  $g = 1 + (J(J+1)+S(S+1)-L(L+1))/2J(J+1)$ . (1 point)
- B. An Fe particle is shaped like a cylinder with diameter 10 nm and length 20 nm. Fe has a bulk crystalline anisotropy of  $5 \times 10^5 \text{ erg/cm}^3$ . It also has surface anisotropy of  $1 \text{ erg/cm}^2$ , i.e., the surface normal is the local easy axis. Assume the direction [001] is aligned with the cylinder axis. Write an expression for the total anisotropy energy of the particle (in ergs). The shape anisotropy may be ignored. (1.5 points)
- C. Ignoring the cubic crystalline anisotropy of the particle in part B, draw the hysteresis loop for fields applied along the cylinder axis and in the radial direction. (1 points)
- D. Including the cubic crystalline anisotropy of the particle in part B, the switching field decreases with temperature owing to two effects. Name these effects and explain how could you experimentally distinguish their relative contribution? (0.5 points)