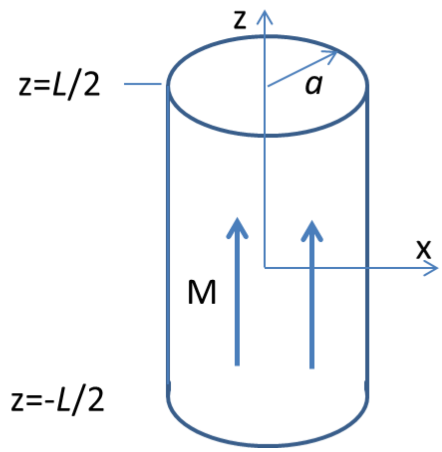
NANO 251A / MATS 251B / MAE 265B HW #1 Due Jan. 22, 2015

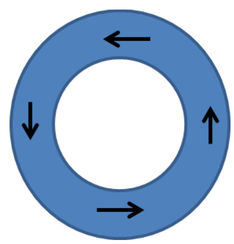
1. Assume a cylinder of magnetic material of length (L) and radius (a). Assume the magnetization (M) is parallel to the axis of the cylinder and along the z-axis. The cylinder is centered at the origin.

a) What is magnetic "charge" density at the surfaces at $z=L/2$ and $z=-L/2$?
b) calculate the magnitude and direction of the magnetic field (H) generated by the magnetic material along the z-axis inside the material ($-L/2<z<L/2$).
c) calculate the magnitude and direction of the magnetic field (H) generated by the magnetic material along the z-axis outside the material ($z>L/2$).
d) Redo, b) and c) but calculate the magnetic flux B.
e) Is the normal of B continuous at $z=L/2$?
f) What the field (H) and magnetic flux (B) inside the magnetic for $a>>L$ (for simplicity assume a goes to infinity).



g) assume a=1 cm and M=1000 emu/cm^3. Plot the magnitude of the magnetic field both inside the magnet ($-L/2<z<L/2$) and outside the magnet ($z>L/2$) for L=10 cm and L=1 cm.
h) From the L=10 results what is the 1/e distance for the fall-off of the field relative to a?

2. Assume you have a donut shaped disk of magnetic materials and the magnetism follows the shape of the donut. If the donut is in the x-y plane and centered at the origin, the magnetization pattern can be described by $\vec{M} = M\hat{\phi}$ in cylindrical coordinates. Will this disk generate an external magnetic field?



3. Assume a cylinder like that shown in (1) where $L>>a$ and is made up of polycrystalline Nickel. If you assume there is no magnetocrystalline anisotropy in the Ni, how much field is required to align the Ni magnetization along the x axis?

4. A cylinder of ferromagnetic material is 6.0 cm long and 1.25 cm in diameter, and has a magnetic moment of 7.45 x 10^3 emu.
a. Find the magnetization of the material.
b. What current would have to be passed through a coil of 200 turns, 6.0 cm long and 1.25 cm in diameter, to produce the same magnetic moment?
c. Why is this only possible with a superconducting wires?

5. If you have a magnetometer that can measure a 10^{-6} emu signal, how thick of a Fe film on a 1 mm x 1 mm substrate can you measure? Give your film thickness in nm and atomic layers.

6. Assume a spherical magnetic particles of radius *R* and magnetization value of M = 1000 emu/cm^3 and exchange parameter A = 1 x 10^{-6} ergs/cm. For each of the following uniaxial magnetic anisotropy values K = 1 x 10^5, 1 x 10^6, 1x 10^7 and 1x10^8 ergs/cm^3 (assuming an attempt frequency of 10 GHz) calculate:

a) The zero-temperature coercive field (assuming the field is along the anisotropy axis).

b) The radius going from single-domain to multi-domain (using the simplified expression in the notes) ground state. Will these answers overestimate or underestimate the critical radius and why? What calculation is needed to accurately calculate the critical radius.

c) The radius for the particle to be ferromagnetic at room temperature for 1 sec.

d) For the radius values determined in c) what would the coercivity values be if measured at 200 K and 100 K for a measurement time of 1 sec.

e) For each of the temperatures in d), what is the characteristic time scale for the particle's magnetization to be stable?

7. For a superparamagnetic particle with strong uniaxial anisotropy (that is the magnetization is always parallel to the anisotropy axis), what is the expected functional form of M vs. H? (Hint, it will not be the Langevin function).