MAGNETIC MATERIALS & DEVICES

Problem Set

13.1

a) Eq. 13.15: $$\chi_m = -\mu_0 \frac{q^2 Z r^2}{4 m_e V}$$, where: $V \rightarrow$ volume of the atom

$Z \rightarrow$ factor to account for multiple electrons in the atom

$V = \frac{4}{3}\pi r^3$, where: $r \rightarrow$ Bohr radius, which is a physical constant $\cong$ to the most probable distance between the nucleus and the electron in a hydrogen atom in its ground state and equal to $\cong 5.29 \times 10^{-11}$ m.

Thus, $$\chi_m = -4\pi \times 10^{-7} \frac{(1.602 \times 10^{-19} C)^2 \times 1 \times (5.3 \times 10^{-11})^2}{4 \times (9.11 \times 10^{-31} kg) \times (6.22 \times 10^{-31}) m^3} \cong -10^{-5}$$

b) Eq. 13.17: $$F = -\frac{d\Delta E}{dZ} \Rightarrow$$

$\vec{B} = \mu \vec{H} = \mu_0 \mu_r \vec{H} = \mu_0(1+\chi_m)\vec{H} = \mu_0(\vec{H} + \vec{M})$

magnetic field strength

$$F = -V \mu_0 \chi_m H \frac{dH}{dz}$$

$m_{frog} = 1$ kg $\Rightarrow$

$$\frac{dH}{dz} = \frac{H}{L_{frog}} = \frac{H}{0.05\,m}$$

$$m \times a = -(0.05)^3 m^3 \times 4\pi \times 10^{-7} H/m \times 10^{-5} \times \frac{H}{0.05\,m} \Rightarrow$$

$$1 \times 9.8\, m/s^2 = -(0.05)^3 m^3 \times 4\pi \times 10^{-7} H/m \times 10^{-5} \times \frac{H}{0.05\,m} \Rightarrow$$

$$H = \_\_\_\_ \; A/m$$

$\langle \vec{x} \rangle = 1\text{Å}$

13.2 A magnetic moment in an externally produced magnetic field has a potentianl eenergy: $U = m \cdot B$, where: m is a magnetic dipole moment

Magnetic interaction: $U_m = \mu_B B$, where $\mu_B = 9.274 \times 10^{-24}\ J/T$

and $U_M = \mu_B \dfrac{\mu_0}{4\pi} \dfrac{2\mu_B}{|x|^3} = \dfrac{(9.274 \times 10^{-24} J/T)^2 \times 4\pi \times 10^{-7} H m^{-1}}{4\pi \times (10^{-10} m)^3} = \simeq 10^{-4}\ eV$

Electrostatic interaction: $U_c = q V_c = \dfrac{q^2}{4\pi\varepsilon_0 r} = \dfrac{(1.602 \times 10^{-19} C)^2}{4\pi \times 8.85 \times 10^{-12} F m^{-1} \times 10^{-10} m} \simeq 14\ eV$

$V_c = q/4\pi\varepsilon_0 r$

13.3 Energy in a magnetic field: $U = 1/2 \int \vec{B} \cdot \vec{H}\, dV = \frac{1}{2} \int \frac{B^2}{\mu} dV \quad \left(\mu = \frac{B}{H} \right)$

a) ferromagnets $\mu >> 1 \rightsquigarrow$ returning energy much lower

An unmagnetized piece of ferromagnetic material has randomly oriented domains. When magnetized by an external field, the domains show greater alignment and some grow at the expense of others. Individual atoms are aligned within domains; each atom acts like a tiny bar magnet.

b) $E = 1/2 \int \vec{B} \cdot \vec{H}\, dV = \frac{1}{2} \int \vec{B} \left(\frac{\vec{B}}{\mu_0} - M \right) dV = \frac{1}{2} \int \frac{\vec{B}^2}{\mu_0} - M \cdot B\, dV$

$B = \mu_0 (H + M)$

13.4

magnetization is the induced moment/volume

from Eq. (13.21): $M = \frac{m}{V} = \mu_B \Delta n = \mu_B^2 B n(E_F) \Rightarrow$

μ_B ↓ spin magnetic moment

$n(E_F)$ fermi energy

$$M = \frac{m}{V} = \mu_B \cdot \frac{n_e}{V} \simeq \mu_B \cdot \frac{n_{atoms}}{V} = \mu_B \cdot \frac{N_A}{a.w.} \cdot \text{density} =$$

$$= 9.27\times10^{-24}\ J/T \times \frac{6.022\times10^{23}}{55.85\ g} \times \frac{7.874\,g}{1\,cm^3} \times \frac{1\,cm^3}{(0.01\,m)^3} = 7.7\times10^{5}\ A/m$$

13.6

$$H = \frac{I}{2\pi r} \Rightarrow I = 2\pi r H = 2\times\pi\times1\times10^{-2}\,m\times300\,Oe\times\frac{1\,A\,m^{-1}}{4\pi\times10^{-3}\,Oe} \Rightarrow I = 1500A$$

γ-Fe_2O_3
(gamma ferric oxide)
coercivity 300 Oe
↓
0.03 Teslas.

The magnetic field from a current source is:

$$B = \mu_0 I/(2\pi r) \Rightarrow$$

$$0.03T = \mu I/(2\pi\ 1cm) \Rightarrow$$

$$I = 1500\,A$$