# MAS.862 P.I.T.
# Problem Set Chapter 13

(13.1)(a) From (13.15) $\chi_m = -\mu_0 \frac{q^2 Z r^2}{4 m_e V}$

Assuming a single electron orbiting at distance $r \simeq 5.3\times10^{-11}\,m$ (Bohr radius)
Thus the effective Volume is $V = \frac{4}{3}\pi r^3 \simeq 6.22\times10^{-31}\,m^3$

Thus for a hydrogen atom: $\chi_m = -4\pi\times10^{-7} \frac{(1.602\times10^{-19}C)^2 \times (5.3\times10^{-11})^2}{4\cdot(9.11\times10^{-31}kg)\times 6.22\times10^{-31}m^3}$

Teslas

$\simeq -10^{-5}$

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

Across the frog drops to zero so: $\frac{dH}{dz} \simeq \frac{H}{l_{frog}} \simeq \frac{H}{0.2m}$

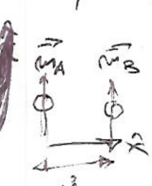
Assuming frog is 0.5kg then we have:

$0.5\times9.8\,kg\,m/s^2 = -(0.2m)^3 \times 4\pi\times10^{-7}H/m \times 10^{-5} \times \frac{H^2}{0.2m}$

or $H \sim 10^5\,A/m$

$\Rightarrow B \sim 1.25\,T$

(13.2) • $\vec{B} = \frac{\mu_0}{4\pi}\left[\frac{3\hat{x}(\hat{x}\cdot\vec{m}) - \vec{m}}{|\vec{x}|^3}\right]$ • From (13.19) an electron has dipole moment $\mu_B = 9.274\times10^{-24}\,J/T$



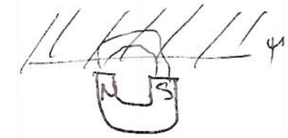

• Assuming they are spaced 1Å away with same dipole moment vectors we have $U_m = \mu_B B$

So $U_m = \mu_B \frac{\mu_0}{4\pi}\frac{2\mu_B}{|x|^3} = \frac{(9.274\times10^{-24}J/T)^2 \times 4\pi\times10^{-7}Hm^{-1}}{4\pi\times(10^{-10}m)^3} \simeq 10^{-4}\,eV$

• $U_c = qV_c = \frac{q^2}{4\pi\epsilon r} = \frac{(1.602\times10^{-19}C)^2}{4\pi\times8.85\times10^{-12}Fm^{-1}\times10^{-10}m} \simeq 14\,eV$

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

(a) For ferromagnets we have $\mu >> 1$



So if the permanent magnet has a field B, the returning energy will be much lower (by a factor of $\mu$). The difference in energy is the reason for the attractive force.

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

Magnetic field lines want to go where is lower/more susceptibility

(13.4) From (13.21) we have:

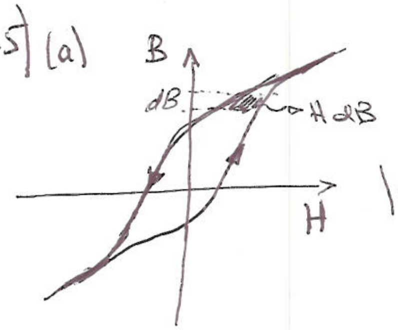
$\boxed{\begin{array}{l}\text{For } Fe_2: \ a.w. = 55.84 \\ \text{density} = 7.874\ g/cm^3\end{array}}$

$M = \frac{m}{V} = \mu_B \cdot \frac{n_e}{V} \simeq \mu_B \cdot \frac{n_{atoms}}{V}$

$\Rightarrow M = \mu_B \cdot \frac{N_A}{a.w.} \cdot \text{density} = 9.27\times10^{-24}\,J/T \cdot \frac{6.022\times10^{23}}{55.85g} \times \frac{7.874g}{1cm^3} \times \frac{1cm^3}{(0.01m)^3}$

$\Rightarrow M \simeq 7.7\times10^5\ A/m$

(13.5) (a)




$\frac{\partial U}{\partial t} = \cancel{\vec{E}\cdot\frac{\partial \vec{D}}{\partial t}} + \vec{H}\cdot\frac{\partial \vec{B}}{\partial t}$ ?

Integrating over the curve and assuming $\frac{\partial B}{\partial t}dt \simeq dB$

$\oint \frac{\partial U}{\partial t}dt = \oint \vec{H}\frac{\partial \vec{B}}{\partial t}dt$

$\Rightarrow U = \oint \vec{H}\,dB = \int_{left} \vec{H}\,dB - \int_{right} \vec{H}\,dB$

(b)

(13.6) ~~Tabla / Aufgabe~~


We know: $H_r = \frac{I}{2\pi r}$ $\rightarrow$ $I = 2\pi r H = 2\times\pi\times 1\,\text{cm} \times 300\,\text{Oe} \times \frac{1\,\text{A m}^{-1}}{4\pi\,10^{-3}\,\text{Oe}}$

$\rightarrow$ $I = 1500\,\text{A}$