(13.1) (a) Estimate the diamagnetic susceptibility of a typical solid.

$$\mathrm{X}_m = -\mu_0 \frac{q^2 Z r^2}{4 m_e V}$$

For Carbon:

$V = \frac{4}{3}\pi(r = 77pm)^3 = 1.9E^{-27}L$

$Z = 12$

$$\mathrm{X} = \left(1.25E^{-6}\frac{m\ kg}{s^2A^2}\right)\frac{(1.6E^{-19}C)^2(12)(77pm)^2}{4(9.1E^{-31}kg)(\frac{4}{3}\pi 77pm^3)}$$

$$\mathrm{X}_m = -0.00033$$

(b) Using this, estimate the field strength needed to levitate a frog, assuming a gradient that drops to zero across the frog. Express your answer in teslas.

Mass of Frog: 22 grams

Volume of frog = 22g / 1 g/ml = 22ml

Height of frog = 30mm

$$F = -V\mu_0 \mathrm{X}_m H\frac{dH}{dz}$$

$$22g * 9.8\frac{m}{s^2} = -(22mL)\mu_0(-.00033)H\frac{dH}{dz}$$

$$H\frac{dH}{dz} =$$

(13.2) Estimate the size of the direct magnetic interaction energy between two adjacent free electrons in a solid, and compare this to size of their electrostatic interaction energy. Remember that the field of a magnetic dipole ~m is B~ = µ0 4π 3x^(x^ · ~m) − ~m |~x| 3 . (13.34)

(13.3) Using the equation for the energy in a magnetic field, describe why:

$$U = \frac{1}{2}(ED + BH)$$

(a) A permanent magnet is attracted to an unmagnetized ferromagnet.

The total energy of the system decreases when free space is replaced by a high permeability material. In that volume, the change in energy is

$$\Delta U = \int BB\mu_0 - \int BB\mu_0\mu_r$$

(b) The opposite poles of permanent magnets attract each other.

The volume of high field decreases as the poles come closer to each other. When they touch, that portion of the field becomes effectively zero volume.

(13.4) Estimate the saturation magnetization for iron at 0 K.

Iron has 2 valence electrons each contributing $\mu_B$.

Density is 7.87g/cc, Atomic weight is 9.27E-26kg

$$M_S = 2\mu_B N = 2\mu_B \frac{\rho}{m}$$

$$M_S = 1.5E6\ A/m$$

(13.5) (a) Show that the area enclosed in a hysteresis loop in the (B,H) plane is equal to the energy dissipated in going around the loop.

(b) Estimate the power dissipated if 1 kg of iron is cycled through a hysteresis loop at 60 Hz; the coercivity of iron is 4×10^3 A/m.

Assume perfectly square hysteresis loop. 1kg of iron is 130mL

$$U = 4M_S\mu_0 H_C V$$

$$P = (60Hz)(1.5E6\ A/m)(4E3\ A/m\,)\left(1\ kg\ /\ 7.87\frac{g}{cc}\right)$$

$$P = 220W$$

(13.6) Approximately what current would be required in a straght wire to be able to erase a γ-Fe2O3 recording at a distance of 1 cm?

300 Oe → 2.4E4 A/m

240 Amps or 1508 Amps?