PHY 202/182 Lab Instructor notes
Lab 5: Paramagnetism and Diamagnetism
Spring 2004

- Put out stop watches.
- Introduction
  - Introduction to the magnetic dipole:
    * Start with a discussion of the electric dipole. Define the dipole moment $\mathbf{P}$. (Need a prop to represent the dipole).
    * An electric dipole feels a torque in a homogeneous electric field but has no net force.
    * The potential energy in an external field is $U = -\mathbf{P} \cdot \mathbf{E}$.
    * Using the Van de Graaf as a prop, discuss the case of a non-constant $\mathbf{E}$.
    * Using $F = -\frac{dU}{dx}$, calculate $F = P\frac{dE}{dx}$.
    * Repeat the above for a magnetic dipole (as an analog).
  - Diamagnetism
    * Occurs in all materials
    * Weak force
    * Induced magnetic moments opposite the applied field
    * Lowest energy is far away (ask is force attractive or repulsive)
  - Paramagnetism
    * Some materials have intrinsic dipoles, usually an unpaired electron (just like a little tiny magnet).
    * These magnetic dipoles align with the applied field
    * Lowest energy near other magnet (ask is force attractive or repulsive)
- We won't be using the small magnets in this lab. The small Niobium (?) magnets are brittle. The students should handle them with care: no clanking noises.
- Samples are mounted with tape on the ends of the rod. Adjust the balance by sliding the torsion wire.
- Demonstrate how to stop and release the bar to dampen oscillations.
- The beam should be horizontal and adjusted to as low as possible without the samples touching the table.
- Good magnets are made of very brittle metal. Be careful not to "clank" or drop them.
- The angles must be converted to radians.

- Typical values for $\kappa$ are $3 \times 10^{-5}\,\mathrm{N \cdot m}$. The deflection for the water sample is typically about 20°. Typical values for the force on the water sample are about 1 to $4 \times 10^{-4}\,\mathrm{N}$; these vary widely since the magnets vary widely in strength.
- At the end of the lab, collect the samples and put away the stop watches.
- The most spectacular demonstration of a paramagnet is a superconductor. We should get high $T_c$ superconductor to use as a demo.
- A table of magnetic susceptibilities can be found in the CRC *Handbook of Chemistry and Physics*, page 9-14. Diamagnetic substances have negative susceptibilities and paramagnetic substances have positive susceptibilities. The tables are given in terms of molar susceptibility (cgs units) although volume susceptibility (dimensionless) would be more appropriate for this lab.
- I have started to compile a list of volume susceptibilities. It is in spreadsheet form.