Phys 3310, HW #12, Due in class Wed Apr 23

Q1. BOUND CURRENTS-I

A) Consider a long magnetic rod, radius a. Imagine that we have set up a permanent magnetization $\mathbf{M}(s,\theta,z) = k\ \hat{\mathbf{z}}$, with k=constant. *Neglect end effects, assume the cylinder is infinitely long.* Calculate the bound currents $\mathbf{K}_b$ and $\mathbf{J}_b$ (on the surface, and interior of the rod respectively). What are the units of "k"? Use these bound currents to find the magnetic field inside and outside the cylinder. (Direction and magnitude) Find the **H** field inside and outside the cylinder, and verify that Griffiths' Eq 6.20 (p. 269) works. Explain briefly in words why your answer might be what it is.

B) Now relax the assumption that it is infinite - if this cylinder was *finite* in length (L), what changes? Sketch the magnetic field (inside and out). Briefly but clearly explain your reasoning. Please draw *two* such sketches, one for the case that the length L is a few times bigger than a (long-ish rod, like a magnet you might play with from a toy set), and another for the case L<<a (which is more like a magnetic *disk* than a rod, really)

Q2. BOUND CURRENTS-II

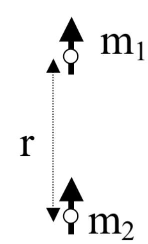
Like the last question, consider a long magnetic rod, radius a. This time imagine that we can set up a permanent *azimuthal* magnetization $\mathbf{M}(s,\theta,z) = c\ s\ \hat{\varphi}$, with c=constant, and s is the usual cylindrical radial coordinate. *Neglect end effects, assume the cylinder is infinitely long.* Calculate the bound currents $\mathbf{K}_b$ and $\mathbf{J}_b$ (on the surface, and interior of the rod respectively). What are the units of "c"? Use these bound currents to find the magnetic field **B**, and also the **H** field, inside and outside. (Direction and magnitude) Also, please verify that the *total bound* current flowing "up the cylinder" is still zero.

Q3. BOUND CURRENTS-III

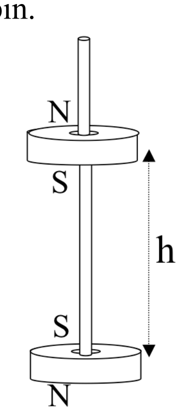
Griffiths 6.12. (p. 272)

Q4. FORCE BETWEEN MAGNETS.

A) In class we have mentioned the fact that toy magnets seem to have a force law which "turns on" quite suddenly as they approach, it doesn't really feel like a $1/r^2$ force. That's because it is not!
Consider two small magnets (treat them as pointlike perfect dipoles with magnetic moments "m1" and "m2", to keep life as simple as possible).
In the configuration shown ("opposite poles facing"), find the force between them as a function of distance r. (Does the *sign* work out for you sensibly?)



B) Let's do a crude estimate of the strength of the magnetic moment of a simple cheap magnet. Assume the atomic dipole moment of an iron atom is due to an (unpaired) electron spin. Last week's homework (Griffiths 5.56) taught us what the magnetic dipole moment of a single electron is (or, just look it up) The mass density and atomic mass of iron are also easy to look up. Consider a small, ordinary, kitchen fridge "button sized" magnet, and make a very rough estimate of its total magnetic moment. Then use your formula from part A to estimate how high (h) one such magnet would "float" above another (if oriented as shown) Does your answer seem at all realistic, based on your experiences with small magnets? (note that such a configuration is not *stable* - why not? I've seen toys like this, but they have a thin wooden peg to keep the magnets vertically aligned, that's how I drew it in the figure)



Phys 3310, HW #12, Due in class Wed Apr 23

Q5. PARAMAGNETICS AND DIAMAGNETS

Make two columns, "paramagnetic" and "diamagnetic", and put each of the materials in the following list into one of those columns. Explain briefly what your reasoning is.
Aluminum, Bismuth, Carbon, Air, a noble gas, an alkali metal, Salt, a superconductor, & water.
(You can look these up if you want to check your answers - but I just want a simple physical argument for how you classified them. If you do look them up, you'll find several in this list are not what you might expect. Write down briefly any thoughts about why a simple argument like you are using might not always work)
By the way - superconductors exhibit the "Meissner" effect, which means they prevent any external magnetic field from entering them - this is the source of "magnetic levitation". That might help you classify them!

Q6. H FIELD.

Go back to Q1, part B, and consider again the "long-ish magnetized rod". Now sketch **H**.
Talk us through your reasoning!
(Think about continuity arguments)

Q7. B INSIDE WIRES.

In a regular household wire, current I flows (uniformly!) down a long straight conducting wire of radius R. Assume the metal is a "magnetically linear" material, and find the magnetic field **B** as a function of distance s from the center of the wire (both *inside* and *outside* the wire)
What are all the bound currents in this problem? (Check yourself by verifying that the total *bound* current is zero)
What can you say about the magnetic field when you take into account susceptibility - consider both Cu wire and Al wire, what happens in both cases? Would it have mattered much if we had treated this problem like a "Chapter 5 problem" and totally neglected the susceptibility of the wire? Would your answer change much if this was a current flowing inside a human body (where the conductive material is basically water)?

EXTRA CREDIT:

Griffiths' problem 6.19 on page 277. It's pretty cool that a very simple (and classical!) model can get you the right order of magnitude here, I was rather amazed...