Phys 3310, HW #12, Due start of class Wed April 22

Q0. SURVEY: http://per.colorado.edu/surveys/assessment
This one is a conceptual content survey. Please do your best, give yourself a good chunk of time at a computer terminal. Do it on your own, without your book or notes.
PLEASE NOTE: you will get FULL CREDIT no matter what your answers are (we won't grade for correctness, merely effort). These are designed as "hard freshman physics conceptual questions", and include some material we haven't focused on this term - just do your best!
ALSO NOTE: There is a timer - it will cut you off at 45 minutes.(I suspect if you hit "back" after that, you could continue, if you really want to finish, but 45 minutes is all I ask for.)

Q1. BOUND CURRENTS-I
A) Consider a long magnetic rod (cylinder) of radius *a*. Imagine that we have set up a permanent magnetization inside, $\mathbf{M}(s,\phi,z) = k\ \hat{\mathbf{z}}$, with k=constant. *Neglect end effects, i.e., 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 **B** 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 answers for **B** and **H** are reasonable.

B) Now relax the assumption that the rod is infinitely long; consider a cylinder of *finite* length. Sketch the magnetic field **B** (inside and out) for *two* cases: one for the case that the length *L* is a few times bigger than *a* (a "long-ish" rod), and second for the case $L<<a$ (which is more like a magnetic *disk* than a rod, really). Briefly but clearly explain your reasoning.

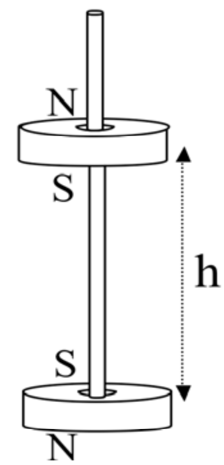
C) Consider again the "long-ish" magnetized rod. Sketch **H**. Are there any free currents in this problem? Do you see any inconsistency in your answers?
*(Hint: It is probably useful to also sketch **B** and **M** in separate diagrams.)*

Q2. BOUND CURRENTS-II
As in the last question, consider a long magnetic rod, radius *a*. This time imagine that we can set up a permanent *azimuthal* magnetization $\mathbf{M}(s,\phi,z) = c\ s\,\hat{\varphi}$, with *c*=constant, and *s* is the usual cylindrical radial coordinate. *Neglect end effects by assuming that 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 zero.

Q3. BOUND CURRENTS-III
Griffiths' problem 6.12 (p. 272) with one clarification: in part (A), use Ampere's Law to compute the B-field due to the bound currents (don't attempt to use the vector potential – that is too messy.)

Q4. FORCE BETWEEN MAGNETS.

A) Consider two small magnets (treat them as pointlike perfect dipoles with magnetic moments $\mathbf{m_1}$ and $\mathbf{m_2}$, to keep life as simple as possible). For the configuration shown ("opposite poles facing"), draw a diagram showing the relative orientation of the magnetic dipoles $\mathbf{m_1}$ and $\mathbf{m_2}$ of the two magnets. Then find the force between them as a function of distance *h*. Explain why the *sign* of the force does (or does not) make sense to you.



B) Now let's do a crude estimate of the strength of the magnetic moment of a simple cheap magnet. Assume the atomic magnetic dipole moment of each iron atom is due to a single (unpaired) electron spin. Find the magnetic dipole moment of an electron from an appropriate reference (and cite the reference). The mass density and atomic mass of iron are also easy to look up. Now consider a small, ordinary, kitchen fridge "button sized" magnet, and make a very rough estimate of its total magnetic moment **M**. Then use your formula from part A to estimate how high (shown as the distance *h*) one such magnet would "float" above another, if oriented as shown in the figure. 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, so that's how I drew it in the figure.)

Q5. B INSIDE WIRES.

A) 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, with magnetic susceptibility χ_m . Find the magnetic field **B** as a function of distance *s* from the center of the wire (both *inside* and *outside* the wire).

B) Compute the total bound current per length of the rod. (Include both volume and surface bound currents.)

C) What can you say about the magnetic field when you take into account susceptibility? Consider both Cu wire and Al wire; what happens in each case? 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)?

Q6. CLASSICAL ATOMIC MODEL OF DIAMAGNETISM

Do Griffiths' problem 6.19 (p. 277).