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

Overall Statistic (Average: 91.08%, Median: 96.11%, Stddev: 11.50%)

Keke: Overall Comment: I found most of the students did much better compared to their homework at the beginning of this semester. I think they have made some progress in your class.

Q1. BOUND CURRENTS-I (Average: 96.63%, Median: 100%, Stddev: 6.30%, Partial Point: 22.2%)

A) (Partial Points: 10, Average: 9.63, Median: 10, Stddev: 0.74) Consider a long magnetic rod, radius a. Imagine that we have set up a permanent magnetization $\mathbf{M}(s,\phi,z) = k\ \hat{\mathbf{z}}$, 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) (Partial Points: 10, Average: 9.7, Median: 10, Stddev: 1.13) 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)

Steve: R. wasn't clear on how to go from bound current to B field. I told him to forget about everything else *except* the (only) current in the problem (K, which looks solenoidal). He and several others then engaged in about a 10 minute effort to reconstruct the Amperian arguments that got us the B field for a solenoid.

Q1B: Lot of worry at first about what changes when the rod length becomes finite. I think there was some concern (since you don't computer B exactly here, it's just a sketch, but they didn't know they didn't have to find it all exactly)

People are often confused about what changes when the solenoid is finite. Several (A. included) were confused about how to procede even in the infinite case - once you get K and J, what do you do? They wanted to start integrating to find A, because that's the formula we had on the board.

This came back on Number 6, see below.

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

Q2. BOUND CURRENTS-II (Average: 93.25%, Median: 100%, Stddev: 10.04%, Partial Point: 11.1%)

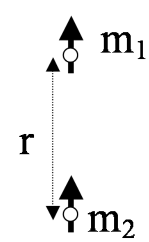
Like the last question, consider a long magnetic rod, radius a. This time imagine that we can set up a permanent *azimuthal* magnetization $\mathbf{M}(s,\phi,z) = c\, s\, \hat{\varphi}$, with c=constant, and s is the usual cylindrical radial coordinate. *Neglect end effects, assume the cylinder is infinitely 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.

Steve: Similar issues to Q1, there was some discussion about how you know the direction of B given the bound currents. R. was confused by the language about "total bound current", she was thinking about one piece of it (surface) which is NOT zero, and then wanted to argue that "bound current is bound, so it can't flow". (But, she also missed lecture today!)

Q3. BOUND CURRENTS-III (Average: 97.5%, Median: 100%, Stddev: 7.86%, Partial Point: 11.1%)

Griffiths 6.12. (p. 272)

Steve: Many people came to me with the same issue. They computed K(bound), and the *formula* has the variable "s" in it. This was confusing them - they didn't realize that s=a at the edge, so it's no longer a variable, it's fixed at one value. Leaving it as a variable for the rest of the problem let to issues.

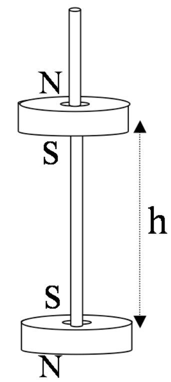


Phys 3310, HW #12, Due in class Wed Apr 23

Q4. FORCE BETWEEN MAGNETS. (Average: 87.88%, Median: 96.25%, Stddev: 24.57%, Partial Point: 11.1%)

A) (Partial Points: 10, Average: 9.28, Median: 10, Stddev: 2.00) 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) (Partial Points: 10, Average: 8.3, Median: 10, Stddev: 3.64) 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)



Keke: Some students got the right force between m1 and m2, but they say the force acting on m2 by m1 is F1 and the force acting on m1 by m2 is F2, so the net force is F=F1+F2.

Steve: Several students asked me how to get started, they had completely forgotten the formula F = Del(m dot B), and so were quite stuck. I was pleased that when C. got "30 meters" as her answer, everyone (including her) laughed at theat unphysical result. S. predicted it should come out "to be centimeters" based on his experience with magnets...

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

Q5. PARAMAGNETICS AND DIAMAGNETS (Average: 97.5%, Median: 100%, Stddev: 7.86%, Partial Point: 11.1%)

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!

Steve: We had some very nice discussions about Q5, several people were going beyond my intended "if it's even, it must be diamagnetic" argument. S. especially was excited to use some chemistry, he knew something about bonding orbitals and unpaired electrons in oxygen (e.g.) and was really into trying to predict these things. Several more questions about the classification of para and diamagnets, I think people don't know if they're supposed to look it up, or derive it, or what. Ss and A. were confused about how to classify a superconductor.

Q6. H FIELD. (Average: 81%, Median: 90%, Stddev: 30.07%, Partial Point: 11.1%)

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)

Keke: lots of them did not realized H=0 in the middle of the rod. They did pretty well in other problems.

Steve: Quite a few people thought I was talking about Q1a, the infinite case, where H=0 everywhere, and so were baffled. When I told them it was the finite case we wanted, they were still pretty stumped. Many questions here. Turns out I haven't talked about "continuity equations" at boundaries in class, which I think this really requires, so they were being pushed to use stuff from readings that hasn't been explicitly covered yet. C. struggled a long time with this one.

Biggest struggle by far was with #6, sketching H for a finite bar magnet. Nobody got it, and I felt like I had to walk many people through almost from start to finish. We had good discussions about it, making physical sense of it, thinking of the analogy to an electret, looking at continuity of lines, thinking about strength (do the H lines "bow out" or "bow in"), and so on.

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

Q7. B INSIDE WIRES. (Average: 81.5%, Median: 95%, Stddev: 27.78%, Partial Point: 11.1%)
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)?

Steve: Some people were confused about what exactly is *given* in the first part. (I should perhaps have said "material of susceptibility chi" so they knew I meant for them to define chi and treat it symbolically as a "given".

EXTRA CREDIT:
Out of the 5 Students: (Average: 92%, Median: 5, Stddev: 17.9%)
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...