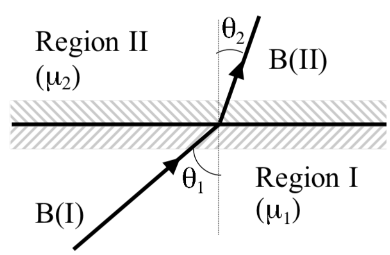
Phys 3310, HW #13, Due in class Wed Apr 30

Q1. SURVEY: www.colorado.edu/sei/surveys/Spring08/Clicker_Phys3310_sp08-post.html
You will get full credit (10 pts) on this homework problem just for filling out this survey (URL above) about the course. We obviously won't "grade" you in any way on your specific responses - your opinions matter and will help us improve this course in the future. *(When I get these results, they will be "anonymized", so I won't specifically connect your answers to your name)*

Q2. SURVEY #2: per.colorado.edu/surveys/EMassessment_sp08.html
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.)

Q3. B AND H IN A CAVITY
Find **B** and **H** at the center of a hollow spherical cavity carved out of a *large* chunk of uniform, linear, magnetic material (susceptibility χ_m) which has total field $\mathbf{B} = B_0\,\hat{\mathbf{z}}$ through its volume. (So, this material will be magnetized, and before the cavity is carved, will have a uniform $\mathbf{H}_0 = (1/\mu_0)B_0\,\hat{\mathbf{z}} - M_0\,\hat{\mathbf{z}}$. (Express your answer in terms of B_0)
Hint: Think of the problem as the <u>superposition</u> of a large totally uniform magnetized system with a sphere of uniform but opposite magnetization) This problem could help you to "model" magnetic materials - knowing B in a cavity would tell you how an atom there would magnetize...

Q4. BOUNDARY CONDITIONS FOR B AND H FIELDS
In class awhile ago, we considered the situation of a static E field spanning a boundary between two different materials (with different dielectric constants, ε)
Do the same thing with static B fields: in the configuration shown in the figure, assuming medium one has relative magnetic permeability μ_1, and medium two has permeability μ_2, find the ratio $\tan\theta_2/\tan\theta_1$. Please show/explain your work clearly.
(Find the ratio in terms of μ_1 and μ_2, that should be simplest. Assume there is no free current anywhere in the figure).



• In the figure as shown, if one of the regions is vacuum, and the other one is paramagnetic, which is which? (I.e. which region is vacuum, region I or region II?) How about if one is vacuum, and one is diamagnetic, then which is which? Briefly explain.

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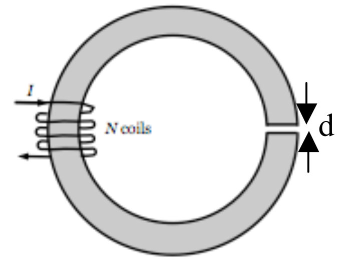
Q5. CONTINUITY B AND H FIELDS

A toroidal piece of "soft iron" (iron that is roughly linear, but has a very large permeability μ characteristic of ferromagnetic materials) has a very thin gap in it, of width "d". A wire carries current I, and is wrapped N times around a section of the toroid. The toroid has a constant cross-sectional area A. Find the B and H fields in the gap.



You may assume: that B (and H and M) inside the soft iron are quite uniform, smooth, and continuous all the way around... except of course in the gap. (Which is continuous through THAT little region, H or B? Why?) Also assume that fringe fields are negligible, and that $\mu/\mu_0 >> 1$. Also, assume that $\mu/\mu_0 >> (2\pi R/d)$, in other words that although the gap may be reasonably small, μ/μ_0(iron) is quite huge, typically of order 1000.

Q6. ANALOGIES BETWEEN E AND B.

Do Griffiths Problem 6.23, just part a.

Feel free to "take" old electrostatic result from earlier in the book without rederiving them. The problem tells you many "conversions" from electrostatic quantities to magnetic ones, but it does NOT tell you what to do about ε or μ in *a medium, so if you encounter those, I would look for alternative formulations which avoid them. (So just e.g., if I had to work with, say,* $\mathbf{D} = \varepsilon\mathbf{E}$, *I would go back to basics and instead write* $\mathbf{D}=\varepsilon_0\mathbf{E}+\mathbf{P}$.)

What you might take away here is that despite many differences between E and B, there are so many parallels that once you've learned one set of problems and techniques, e.g. from Chapters 3 and 4 for E fields, you have automatically solved a large set of different-looking problems!

Q7. POWERFUL MATH NOTATION

Do Griffiths Problem 6.22

Comment: This is a derivation of Eq. 6.3 (which I never proved in class or notes!), i.e. proving $\mathbf{F} = \nabla(\mathbf{m}\bullet\mathbf{B})$. *I think you may find this to be a challenging problem. Proceed with care, take your time, use lots of paper. Think hard about symbols and notation. Don't give up, the proof "solves itself" if you keep on going! Although this method may look pretty awful to you if you've never seen this "trick" before, the methods developed in this problem are really THE WAY that many proofs (in many physics courses you will take in the future) are done! You may have seen this* method *before - but if not, you introduce numerical subscripts (1,2,3) instead of (x,y,z) to describe Cartesian coordinates, and you introduce the "Kronecker delta",* δ_{ij} *which is a shorthand, DEFINED to be +1 if i=j, and 0 otherwise. It's a convenient notation - you'll see it many times in the future. Same thing for the "Levi-Civita" symbol,* ε_{ijk}, *(which is defined in this Griffiths problem). It takes getting used to, but once you've practiced a little with Levi-Civita, Kronecker delta, and this "ijk" notation, many proofs (like e.g. the identities in the front flyleaf) become mechanical, and thus easy. It becomes mere "careful bookkeeping" to prove many otherwise formidable things!*

EXTRA CREDIT: ***REFEREE REQUEST***

Do Griffiths Problem 6.28.

This is a pretty cool one - I was surprised and intrigued by the outcome. Given your work on several problems from this set, and using results from earlier in the book (and from earlier problem sets you've done!) for E fields, you don't have to do much new calculating here, it's mostly pulling together things we've done before. To satisfy the funding agency, you should probably consider all of the "canonical" cavity shapes: needle-like, wafer-like, and spherical.