Information on the third midterm

The first midterm will be held in class (136 Loomis) on Wed, April 23. The exam is open book, and open notes. There are three problems covering electrostatics in materials, magnetostatics, and magnetostatics in materials. Work the three problems in the examination booklets and box your final answer. Partial credit will be given if I can follow your work. No calculator will be necessary. If you will arrive on time for the exam you will have 50 minutes to work the exam.

The final deadline for homework 10 will be Monday, April 21 < 5pm so I can post solutions to help you prepare for the exam. I will hold additional office hours from 2:30 to 4:30 pm on Tuesday, April 22 for exam questions.

How to prepare for the third hourly.

The best way is to review all of the homework and posted homework solutions with the following in mind.

1. Be familiar with how to calculate bound (volume and surface) charges from the polarization.
2. Be familiar with how to calculate bound (volume and surface) currents from the magnetization.
3. Be familiar with the concept of frozen-in polarization for electrets and frozen-in magnetization in permanent magnets.
4. Be able to calculate the magnetic field from the Biot-Savart and Ampere law.
5. Be very familiar with the magnetic solenoid, and current sheet.
6. Understand the relationship between the current, surface current $\vec{K}$, and volume current $\vec{J}$, how to calculate them from charge densities and velocities and how to convert between them.
7. Understand how surface charges and currents lead to discontinuities in the electric fields and potentials and magnetic fields and potentials.
8. Be able to calculate the magnetic vector potential from the magnetic field using the “flux” method and be able to check your answer using the curl of the magnetic field.
9. Be familiar with the use of the auxiliary fields $\vec{H}$ and $\vec{E}$ and their use in computing polarization, magnetization, bound charges and bound currents.

Here are two problems (and some possibly correct answers) to help you prepare for the 3rd midterm which we will discuss in a lecture near the exam date.

(1) An unusual spherical electret has a polarization of the form $\vec{P} = P_0\, r\, \hat{r}$ from $0 < r < b$ and is 0 for $r > b$. There is no free charge anywhere.

a) Compute all volume and surface bound charge densities.

Answers: $\rho_b = -3P_0$ for $r < b_b$; $\sigma(r = b) = b\, P_0$

b) Show that the total bound charge is zero.

c) Use Gauss's Law to compute $\vec{E}$ everywhere.

d) Compute the stored energy using $U' = \frac{1}{2}\int_{\text{all space}} \vec{D}\bullet\vec{E}\, d\tau$

We now add a thin, metal shell of radius $a < b$ with a free charge of Q. We still have a polarization of $\vec{P} = P_0\, r\, \hat{r}$ for $r < b$.

e) Compute the stored energy using $U' = \frac{1}{2}\int_{\text{all space}} \vec{D}\bullet\vec{E}\, d\tau$ for the spherical electret plus metal shell. $\boxed{U' = \frac{Q}{8\pi\varepsilon_0 a} - \frac{QP_0}{4\varepsilon_0}\left(b^2 - a^2\right)}$

(2) An unusual, long, cylindrical permanent magnet has a magnetization of $\vec{M} = k\, s\, \hat{\phi}$ for $s < R$ and zero otherwise. There are no free charges or currents anywhere else.

(a) Find the bound current density $\vec{J}_b$ and surface density $\vec{K}_b$ everywhere.

(b) Use Ampere's Law to find $\vec{B}$ everywhere

(c) Use $\oint A\bullet d\ell = \int_S \vec{B}\bullet d\vec{a}$ to find the vector potential everywhere and check your result using $\vec{B} = \vec{\nabla}\times\vec{A}$.

Answers: $\vec{A}(s < R) = -\mu_0 \frac{ks^2}{2}\hat{z}$; $\vec{A}(s > R) = -\mu_0 \frac{kR^2}{2}\hat{z}$