Phys 332
Electricity and Magnetism II
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Homework 0

## Physics — Magnetic Materials and Displacement Current

**1:** Wangsness 20-1. Add the following: You have a 5 cm cube which has this maximum magnetization. You are located 1 m away from it in the direction of $\vec{M}$. Estimate the strength of the magnetic field at your location. Then repeat the entire problem if the cube is made of iron with a molecular weight of 55.8 g/mole and a density of 7870 kg/m$^3$.

**2:** An infinite magnetized slab is centered on the xy plane and stretches from $z = -d$ to $z = +d$. It has a magnetization $\vec{M} = M_0\hat{y}$. Determine the magnetization current densities and draw them and determine the magnetic field inside and outside the slab.

**3:** An infinite cylinder of radius $a$ is centered on the z axis. It has a magnetization $\vec{M} = M_0\hat{x}$. Determine the magnetization current densities and draw them and determine the magnetic field on the z axis. Additionally, verify that the net charge transfered across a circular cross section is zero. (You should compare this with Wangsness 10-12 which you solved earlier.)

**4:** An infinite wire of radius $a$ has a constant current density $\vec{J} = J_0\hat{z}$. It surrounded by an infinite cylindrical *lih* described by $\mu > 1$ which stretches from $a$ to $b$.
**a:** Determine $\vec{H}$, $\vec{B}$ and $\vec{M}$ everywhere.
**b:** Determine the magnetization current densities and draw them. You will find that $\vec{J_M} = 0$. Do you understand how this can be when $\vec{M}$ is in $\hat{\phi}$ and certainly appears to curl around the z axis? Explain. Additionally, verify that the net charge transfered across a circular cross section is zero.
**c:** Check and make sure that the boundary conditions for $\vec{H}$ and $\vec{B}$ are satisfied at $\rho = a$ and $\rho = b$.
**d:** Determine the total magnetic energy in a cylinder of length $L$ and radius $\rho$ where $\rho > b$.

**5:** Refer back to problem 3. We only found the magnetic field on the z axis since the integrals would have been quite difficult off the axis. Let's find a different way to solve this. Determine $\rho_m$ and $\sigma_m$ for this magnetization. Use these to determine a general solution for $\phi_m$ everywhere. Determine the exact solution by applying appropriate boundary conditions on $\phi_m$ and $\vec{H}$. Find the demagnetizing factor. Then get $\vec{B}$ everywhere and verify that you get the same answer on the axis as you did in problem 3.

**6:** Wangsness 20-21.

**7:** Wangsness 21-1. Consider the plate to be effectively infinite.

**8:** A parallel plate capacitor with plate area A (which is effectively infinite) is charged so that the charge density on each plate is $\pm\sigma_{ch}$. It is then disconnected from the battery. A linear nonmagnetic dielectric described by permittivity $\epsilon$ and conductivity $\sigma$ is inserted between the plates so that the capacitor can discharge.
**a:** The actual current density between the plates $\vec{J}$ can be calculated two ways: one directly from the definition of current $I = \frac{dq}{dt}$ and one from Ohm's Law. Use both of these to determine $\sigma_{ch}(t)$. Explain the dependence of your answer upon $\sigma$ and $\epsilon$. You may assume that the electric field can be calculated from the charges and that the time varying magnetic field is negligible (a quasistatic approximation).
**b:** Determine $\vec{H}$ at a radius $\rho$ away from the symmetry axis of the plate. Do the two sources of magnetic field add or subtract from each other in this situation? Explain.