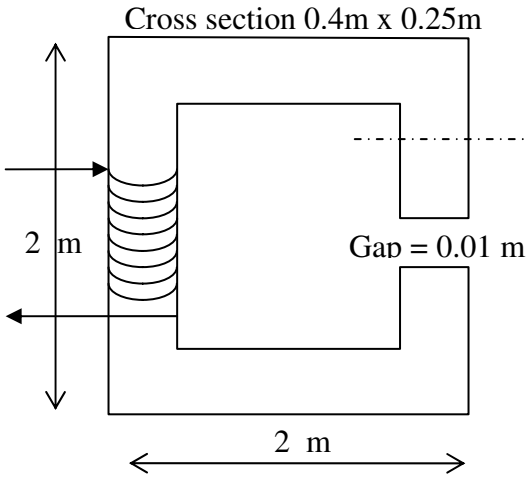
EC301: Quiz II 20 marks March 25, 2009

1. Uniform $\vec{E}$ and $\vec{B}$ fields are oriented at right angles to each other inside the velocity filter equipment (for charged particles). A stream of charged particles which is a mixture of electrons (e^-), protons (H^+), and α-particles (He^{2+}), are allowed to pass at right angles to both the fields. If the magnitude of $\vec{B}$ is fixed at 0.5 mWb/m^2, find the respective values of $\vec{E}$, to obtain undeflected stream of only electrons, only protons, and only α-particles those are traveling with a speed of $8\times10^6 m/s$. (1+1+1)

2. A circular-cross-section conductor of radius 1.5 mm carries current of $i_c = 5.5\sin\left(4\times10^{10}t\right)$ μA. What is the amplitude of the displacement current density, if σ = 35 MS/m and ε_r = 1? If a parallel plate capacitor (Area = 5 mm^2, d = 0.5 mm, ε_r = 10, σ ~ 0) is introduced at the mid-way of the conductor to obtain a capacitive effect and same i_c is allowed to flow through the conductor, calculate the corresponding amplitudes of displacement and conduction currents through capacitor. (2+1)

3. An EM wave is traveling in a medium characterized by $\sigma = 0, \mu = \mu_0, \varepsilon = 4\varepsilon_0$ and $\vec{E} = 20\sin\left(10^8 t - \beta z\right)\hat{a}_y$ V/m, calculate $\vec{\beta}$ and $\vec{H}$. (2+2)

4. A C-shaped iron electromagnet (shown in Fig) is designed to withstand a gap-closing force of 9.8 x 10^4 N. Assume no fringing. What is the maximum allowable current for which the force will not exceed this value. The magnetic coil has 10,000 turns, with a relative permeability of 1000. (4)



5. Assume that a sinusoidal current of frequency 10^3 kHz is applied to the coils of the electromagnet in Problem 4. Assuming σ = 10^7 /Ohm-m, (1+2+3)

   a. determine the skin depth in the core material
   b. plot the eddy current density across the yoke cross section, shown by the dotted line
   c. if you wanted to reduce cost, what is the minimum permissible cross-section that you can use and still have a reliable electromagnet? Explain your reasoning.