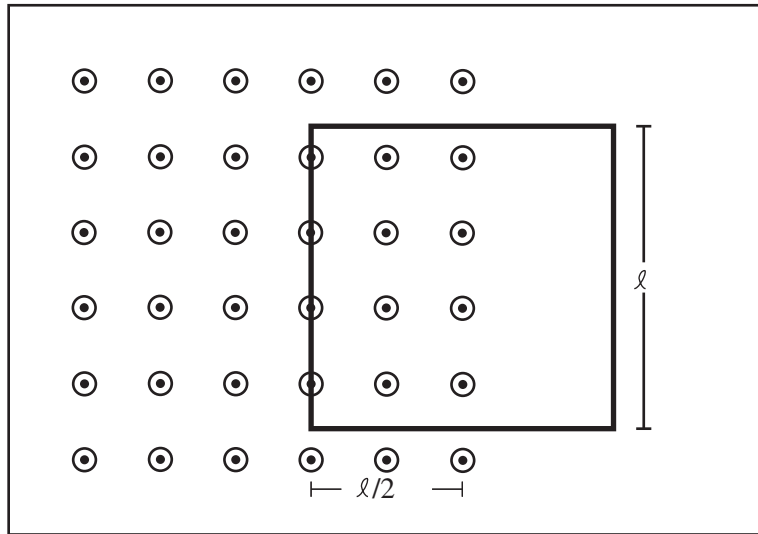


## Electricity and Magnetism - Test 3 - Spring 2010

Work four of the six problems. Place the problems in the order you wish them graded. The first two problems form the first half test; the second two problems form the second half test.

**Problem 3.1** Consider two concentric strongly conducting spherical shells where the smaller has outer radius  $a$  and the larger inner radius  $c$ . The volume between the shells is filled with two weakly conducting materials. The space from  $r = a$  to  $r = b$  contains a material with conductivity  $\sigma_1$ . The space from  $r = b$  to  $r = c$  contains a material with conductivity  $\sigma_2$ . Compute the resistance between the shells (between  $r = a$  and  $r = c$ ). Note,  $a < b < c$ .

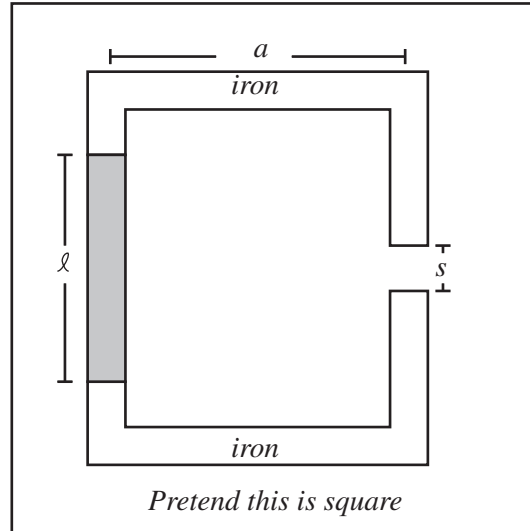
**Problem 3.2** An aluminum square with resistivity  $2.65 \cdot 10^{-8} \Omega\text{m}$  is placed halfway inside a magnetic field. The magnetic field is being turned off and the magnitude of the field obeys  $B_0 e^{-t/\tau}$  where  $\tau = 2\text{s}$  and  $B_0 = 0.2\text{T}$ . The aluminum square has side length  $\ell = 2\text{cm}$  and cross-sectional area  $A = 1\text{cm}^2$ . Compute the force exerted on the loop at time  $t = 0$ . Does the force tend to push the loop out of the field or draw the loop into the field?



**Problem 3.3** As part of an honors project in UPII this semester, a student used a stack of NdFeB magnets to power a hand generator. Each magnet was a cylinder of height  $h = 1\text{mm}$  and radius  $r = 1\text{cm}$ . The student made the approximation that the magnetic field of a stack of six magnets was six times the magnetic field of one. The magnetization of NdFeB is  $1.02 \cdot 10^6 \text{A/m}$ . Compare the field at the center of a single magnet with the field at the center of a stack of six magnets. You may model the bound current of a single magnet as a ring, but may not use this model for the stack. You may use the formula for the field of the current distribution of the stack if you included it on your formula card, if not you will have to re-derive it.

**Problem 3.4** The region between  $z = -a$  and  $z = +a$  contains a changing electric field  $\vec{E} = E_0 \sin(\omega t) \hat{x}$ . Compute the magnetic field at points  $z > a$ .

**Problem 3.5** A horseshoe magnet is formed into a square. It is made using a section of NdFeB permanent magnetic material with magnetization density  $1.02 \cdot 10^6 \text{ A/m}$  of length  $\ell = 2 \text{ cm}$ . The square has average side length  $a = 3 \text{ cm}$  and a gap with width  $s = 1 \text{ cm}$ . Compute the magnetic field in the gap. The relative permeability of iron is 100. Note, this problem may be worked in the same manner as the other magnets formed of rings of various materials worked in the homework.



**Problem 3.6** A cylindrical stainless steel channel with relative permeability  $\mu_r$ , inner radius  $a$  and outer radius  $b$ , confines a plasma with current density

$$\vec{J} = \frac{J_0 a}{s} \sin\left(\frac{\pi s}{a}\right) \hat{z}$$

where the axis of the solenoid is the  $z$ -axis and  $J_0$  is a constant. Compute  $\vec{H}$ ,  $\vec{B}$ , and  $\vec{M}$  everywhere.