For problems 1 and 2, consider the UU core inductor below. This inductor has two coils. Each coil is wound in a direction such that positive current will cause positive flux to flow in a clockwise direction. Each coil has N turns and has a packing factor of \( p_f \). The permeability of air is denoted \( \mu_0 \), the permeability of the magnetic material is \( \mu, \mu_0 \), where \( \mu \) is the relative permeability of the material. The conductivity of the conductor in the coil is \( \sigma \).

1) 32 pts. Neglecting leakage and fringing flux, derive an expression for the electromagnetic force of attraction between the cores in terms of the coil currents \( i_1 \) and \( i_2 \), \( N \), \( \mu_0 \), \( \mu_r \), and the dimensions in the figure.

2) 32 pts. Suppose the second current is given by \( i_2 = I_2 \cos(\omega t) \) while the first coil is open circuited. Derive an expression for the voltage across the first coil in terms of \( I_2 \), \( \omega \), \( N \), \( \mu_0 \), \( \mu_r \), and the dimensions in the figure.
The following problems are grades as follows:
No Answer: 0
Completely Correct Answer: +4
Partially or Completely Incorrect Answer: -2 (i.e. negative score on problem)

3.) Does magnetic hysteresis cause a field to be non-conservative?
4.) Does magnetic saturation cause a field to be non-conservative?
5.) If you are given expressions for current in terms of flux linkages, is it more direct to find field energy or co-energy?
6.) What reference frame would be appropriate for the analysis of an unsymmetrical 3-phase system?
7.) Where would phasor analysis be more useful: on qd0 variables in the stationary reference frame or on qd0 variables in a synchronous reference frame?
8.) Is the arbitrary reference frame transformation $K_r$ always invertible?
9.) Not counting the arbitrary reference frame; what are the three most commonly used frames of reference?
10.) Consider a delta connected component. If the line-to-line voltages are transformed, are there any conditions that can lead to a non-zero zero-sequence voltage (either as a transient or in the steady-state)?
11.) Consider a delta connected component. If the currents in the branches forming the delta are transformed, are there any conditions that can lead to a non-zero zero-sequence current (either as a transient or in the steady-state)?