1. The core shown below is divided in half and composed of two different materials with different permeabilities. $\mu_1 = 0.001$ and $\mu_2 = 0.005$. $N_1 = 100$ and $N_2 = 50$. Assume the length of the whole flux path is 20 cm and the cross-sectional area of the core is $5 \times 10^{-5}$ m$^2$.

a. (8 points) Draw the complete magnetic circuit, including source polarities and reluctance values.

b. (8 points) Find the self inductance of coil #2.

c. (8 points) Find the mutual inductance between the coils.

2. A circuit including a 220/440V power transformer is given below. Assume the conditions given represent full-load conditions.

a. (9 pts) Find the efficiency of the transformer.

b. (9 pts) Find the Voltage Regulation for this transformer.

c. (5 pts) If three transformers like the one above were connected in a Delta-Wye three-phase set-up, what would the transformer bank voltage ratings be?
3. The results of the open circuit and short circuit tests for a 550/220 V, 60 Hz transformer are given below.

<table>
<thead>
<tr>
<th>Open Circuit Test</th>
<th>Short Circuit Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured on Low Voltage Winding:</td>
<td>Measured on High Voltage Winding:</td>
</tr>
<tr>
<td>P = 500 W</td>
<td>P = 300 W</td>
</tr>
<tr>
<td>I = 10 A</td>
<td>I = 15</td>
</tr>
<tr>
<td>V = 220 V</td>
<td>V = 30 V</td>
</tr>
</tbody>
</table>

a. (8 pts) Find the series impedance, \( R_s + j X_s \)

b. (8 pts) Find the core impedances, \( R_c \) and \( X_m \)

c. (4 pts) Draw and label the circuit for the transformer above, referring all impedances to the high voltage winding

d. (5 pts) Explain in your own words and with sketches how the clamp-on current probes used in lab are transformers.

4. Two balanced 3-phase loads are connected in parallel. The loads are connected to a balanced, 3-phase, 500 V source through a transmission line with impedance \( 0 + j 2 \) \( \Omega \) per phase. One load is Y-connected with impedance of \( 21 + j 30 \) \( \Omega \)/phase and the other is Delta-connected with impedance of \( 15 + j 45 \) \( \Omega \)/phase.

a. (5 points) Draw the one-line diagram for this circuit, complete with impedance values and source voltage.

b. (7 points) Find the line current in each of the three lines.

c. (8 points) Find the total 3-phase, complex power delivered by the source.

d. (7 points) Assume the load takes \( 1000 + j 3000 \) VA (not the correct numbers), and the line voltage at the load is 500 V (again not the correct number). We want to add a Delta-connected 3-phase capacitor bank at the terminals of the load to improve the power factor. If we add a 10 \( \mu \)F per phase, what is the new total power factor?