Consider the magnetic structure drawn below. The steel has infinite permeability. Depth into the page is 1.5 cm. All air gaps are the same dimensions: 1 cm wide, 2 mm long. $N_1 = 300$, $N_2 = 100$.

a. Draw the magnetic equivalent circuit. Mark all polarities, and find all reluctances numerically.

b. Determine the inductance matrix for the device that relates $\lambda_1$ and $\lambda_2$ to $i_1$ and $i_2$. 
A particular machine has the following \( \lambda - i \) relationship:

\[
\begin{bmatrix}
\lambda_1 \\
\lambda_2 \\
\lambda_3
\end{bmatrix} =
\begin{bmatrix}
L_0 & L_1 & L_2 \cos 2\theta \\
L_1 & L_0 & L_2 \sin 2\theta \\
L_2 \cos 2\theta & L_2 \sin 2\theta & L_3
\end{bmatrix}
\begin{bmatrix}
i_1 \\
i_2 \\
i_3
\end{bmatrix}
\]

where \( L_0, L_1, L_2, \) and \( L_3 \) are constant, and \( \theta \) is the position variable for the rotor. For parts c \& d, suppose \( i_1 = \sqrt{2}I_e \cos (\omega_f t), i_2 = \sqrt{2}I_e \sin (\omega_f t), i_3 = I_f, \theta = \omega_m t + \phi \). Useful identities:

\[
\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B
\]
\[
\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B
\]

a. Find the co-energy \( W_{jm}(i_1, i_2, i_3, \theta) \).
b. Find the torque \( T_{jm}(i_1, i_2, i_3, \theta) \).
c. Determine the relationship between \( \omega_e \) and \( \omega_m \) such that the torque is no longer a function of time.
d. For frequencies that satisfy (c), determine the average torque \( T_{\text{ave}}(I_f, I_s, \phi) \).
Problem M.3

Calculate the power delivered by the 3-phase source for the following system (sources, lines, and loads are balanced):
Problem M.4  

A three phase 100kV (L-N) Y-connected motor consumes 60MW at a power factor of 0.8 lagging. If this motor is connected to a three phase Y-connected voltage source using a transmission line with a transmission matrix of $T$, what is the phase current of the source?

$$T = \begin{bmatrix} 0.99 & 0.2 \angle 80^\circ \\ 0.001 \angle 90^\circ & 0.99 \end{bmatrix}$$
Determine the Thevenin Voltage and Thevenin Resistance for the circuit below.
For the following circuit, find $R$, $I$, and $a$. All transformers and components should be assumed to be ideal.