ECE 3614  
FUNDAMENTALS OF ENERGY SYSTEMS  

HOMEWORK SET #3  
MAGNETIC CIRCUITS

3-1. Determine the following quantities given the magnetic circuit shown below:  (a.) the total reluctance of the magnetic core  (b.) the total magnetic flux within the core and  (c.) the magnetic flux densities at point A and point B.  Assume \( I = 2 \text{ A} \), \( N = 100 \), \( \mu_r = 1500 \) and the depth of the core is 10 cm.

![Magnetic Circuit Diagram](image)

**Ans.**  (a.) \( \chi_{total} = 114945 \text{ H}^{-1} \), (b.) \( \psi_m = 1.74 \text{ mWb} \), (c.) \( B(P_1) = 0.218 \text{ T} \), \( B(P_2) = 0.290 \text{ T} \)

3-2. The source in the magnetic circuit below generates magnetic flux in the two air gaps. Assume \( I = 0.4 \text{ A} \), \( N = 750 \), and the reluctance of the core is negligible in comparison to that of the air gaps. Determine  (a.) the total magnetomotive force  (b.) the total magnetic flux through each air gap (\( \psi_{m1} \) and \( \psi_{m2} \)) and (c.) the magnetic flux density in each air gap (\( B_1 \) and \( B_2 \)).

![Magnetic Circuit Diagram](image)

**Ans.**  (a.) \( NI = 300 \text{ A-turns} \), (b.) \( \psi_{m1} = 2.26 \text{ mWb} \), \( \psi_{m2} = 1.51 \text{ mWb} \), (c.) \( B_1 = 0.377 \text{ T} \), \( B_2 = 0.189 \text{ T} \)
3-3. The two-pole synchronous machine shown below is characterized by 3 mm air gaps, a rotor pole face area of 0.1 m², and a magnetomotive force of 2000 A-turns. Neglect fringing and determine the total magnetic flux in the rotor ($\psi_{mr}$) and the stator ($\psi_{ms}$) assuming the reluctance of the rotor and stator are negligible.

\[
\psi_{mr} = \text{41.89 mWb, } \psi_{ms} = \text{20.95 mWb}
\]

3-4. A toroid (mean radius = 10 cm, core cross-sectional area = 8 cm²) is made of silicon sheet steel and wound with 250 turns. The magnetization curve for silicon sheet steel shows that a core flux density of 1.3 T is achieved at a magnetic field of 700 A/m. (a.) Determine the toroid coil current $I$ required to produce a magnetic flux density of 1.3 T in the toroid core. (b.) Determine the relative permeability of the silicon sheet steel from the magnetization curve data (c.) If an air gap of length 3 mm is cut out of the toroid, determine the toroid coil current required to keep the core flux density at 1.3 T.

\[
\text{Ans. } (a. ) \quad I = \text{1.76 A (b.) } \mu_r = \text{1478 (c.) } I = \text{14.16 A}
\]

3-5. Assume the toroid with an air gap from Problem 3-4(c.) is wound with two separate coils (coil #1 has $N_1 = 100$ turns and coil #2 has $N_2 = 200$ turns). Assume the two coils are connected in series (carry the same current). Determine the current required to produce a core flux density of 1.3 T if the magnetic fluxes produced by the two coils are (a.) aligned in the same direction (b.) oriented in opposite directions (c.) Determine the magnetic field in the air gap when the magnetic fluxes are aligned in the same direction (d.) Determine the self-inductances of the two coils.

\[
\text{Ans. } \quad (a.) \quad I = \text{11.80 A (b.) } I = \text{35.41 A (c.) } H_g = \text{1.03 MA/m (d.) } L_1 = \text{2.94 mH, } L_2 = \text{11.75 mH}
\]

3-6. Consider a coil wound on a magnetic core driven by either voltage source #1 [120 V-rms, 60 Hz] or voltage source #2 [100 V-rms, 50 Hz]. Determine (a.) the ratio of eddy current losses in the core ($P_{el}/P_{e2}$) for the two voltage sources (b.) the ratio of hysteresis losses (assume $n = 2$) in the core ($P_{hl}/P_{h2}$) for the two voltage sources.

\[
\text{Ans. } \quad (a.) \quad P_{el}/P_{e2} = \text{1.44 (b.) } P_{hl}/P_{h2} = \text{1.20}
\]