ECE 431 homework #2 (Due – Monday, February 10, 2020)

Problem 2.1

The coils of the magnetic circuit shown in Fig. 1 are connected in series so that the mmfs of paths *A* and *B* both tend to set up flux in the center leg *C* in the same direction. The coils are wound with equal turns, N_1=N_2=120. The dimensions are:

Cross-section area of A and B legs = 8 cm^2
Cross-section area of C leg = 16 cm^2
Length of A path = 17 cm
Length of B path = 17 cm
Length of C path = 5 cm
Air gap length = 0.4 cm

The material is M-5 grade, 0.012-in steel. Neglect fringing and leakage. (Refer to textbook Fig 1.10 for M-5 steel)

a. How many amperes are required to produce a flux density of 1.3 T in the air gap?
b. Under the condition of part (a), how many joules of energy are stored in the magnetic field in the air gap and in the core? Based upon this stored energy, calculate the inductance of this series-connected winding.
c. Calculate the inductance of this system assuming the core to be of infinite permeability. Compare your inductance with the value calculated in part (b).

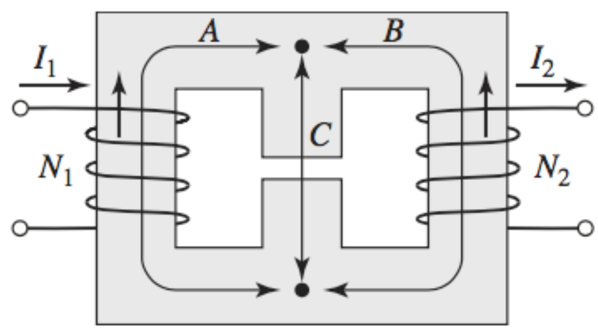

Fig. 1. Magnetic circuit for Problem 2.1

Problem 2.2

A transformer is made up of a 1200-turn primary coil and an open-circuited 80-turn secondary coil wound around a closed core of cross-sectional area 60 cm^2. The core material can be considered to saturate when the rms applied flux density reaches 1.45 T. What maximum 60-Hz rms primary voltage is possible without reaching this saturation level? What is the corresponding secondary voltage? How are these values modified if the applied frequency is lowered to 50 Hz?

Problem 2.3

The resistances and leakage reactances of a 40-kVA 60-Hz 7.97-kV-V:240-V single-phase distribution transformer are

$$R_1 = 40\ \Omega \qquad R_2 = 37\ m\Omega$$
$$X_{l1} = 42\ \Omega \qquad X_{l2} = 40\ m\Omega$$

where subscript 1 denotes the 7.97-kV winding and subscript 2 denotes the 240-V winding. Each quantity is referred to its own side of the transformer.

a. Draw the equivalent circuit referred to (i) the high- and (ii) the low-voltage sides. Label the impedances numerically.
b. Consider the transformer to deliver its rated kVA to a load on the low-voltage side with 240 V across the load. (i) Find the high-side terminal voltage for a load power factor of 0.87 power factor lagging. (ii) Find the high-side terminal voltage for a load power factor of 0.87 power factor leading.
c. Redraw the equivalent circuit and label the impedances in 'per-unit'.

Problem 2.4

A three-phase Y-Y transformer is rated at 25 MVA, 13.8-kV:69-kV and has a single-phase equivalent series impedance $60 + j\ 350\ m\Omega$ referred to the low-voltage winding.

a. A three-phase short circuit is applied to the low-voltage winding. Calculate the voltage applied to the high-voltage winding which will result in rated current into the short circuit
b. The short circuit is removed and a three-phase load is connected to the low-voltage winding. With rated voltage applied to the high-voltage winding, the input power to the transformer is observed to be 18 MW at 0.8 power-factor lagging. Calculate the line-line terminal voltage at the load.