The first 2 problems reinforce basic magnetic circuit relationships for flux, flux density, number of turns, reluctance, flux linked, mean path length, magnetic field intensity, inductance, etc. The next problems consider transformers. I've constructed these similar to study-guide questions, adding useful observations and hints. Refer to handout on e-mag basics of magnetic circuits.

H9.1 - This is a fairly simple one to begin with, to get the basic idea. Note that air has $\mu_R=1$. The core is simplistically assumed to have $\mu_R=\infty$, which makes the reluctance of the core essentially zero – thus we assume that the airgap provides essentially the total magnetic reluctance that the flux flows through. For typical magnetic steels used in transformers, μ_R may be ~8000, so this is actually not a terrible assumption, at least it will not result in large error. Flux leakage of coil and fringing of air gap are neglected. Calculate:

$$I = 4A \qquad A_g = 16 \ cm^2$$
$$N = 500 \ turns$$
$$\ell_g = 2 \ mm \qquad \mathcal{R} = \frac{\ell}{\mu A}$$
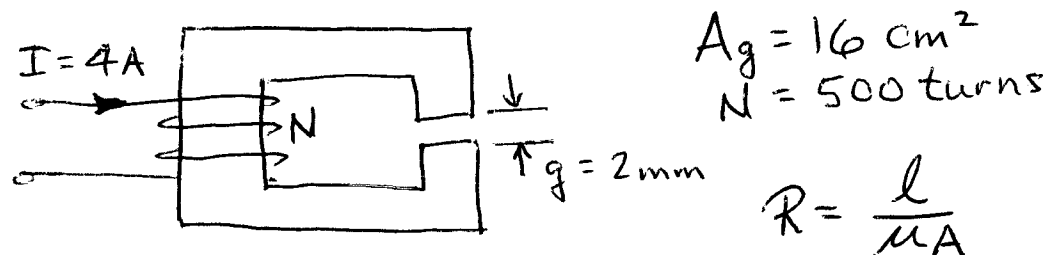
a) The magnetic flux flowing thru the core and across the airgap.
b) The flux linked by the coil.
c) The coil inductance

H9.2   A toroid of circular cross-section is made of magnetic steel with relative permeability of 2500. A dc current of unknown magnitude is flowing in the coil, resulting in magnetic flux density in the core of 1.25 Tesla.

$$N = 250 \ turns$$
$$B = 1.25 \ T$$
$$\mu_r = 2500$$

8 cm   12 cm
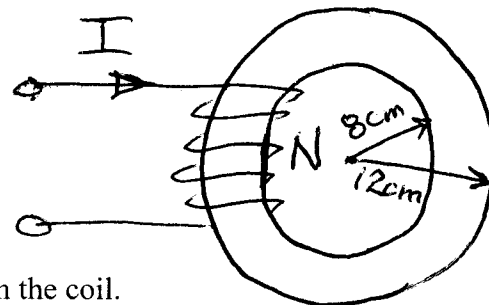
a)   Calculate the current that is flowing in the coil.
b)   Determine the magnetic flux in the core.
c)   Next, the core is modified by cutting a 10-mm air gap across the toroid. Determine how much current must flow in the coil now to produce the same amount of flux as in part b).
d)   For operating conditions of c), calculate the magnitude of H: i) along the steel core, and ii) in the air gap.
e)   Calculate the inductance i) for initial magnetic circuit of part a), and ii) for modified circuit of part c). What is the effect of an air gap on inductance?
f)   How much energy is stored in this inductance: i) in part a), and ii) in part c). Comment on how the addition of an air gap changes the properties of this magnetic circuit.

H9.3   Ideal transformers (refer to class notes and §11.1) pass a given amount of watts and vars through while changing (transforming) the voltage level. Polarity marks keep track of the relative phase angles of the voltages and currents on primary and secondary.

    a)   Consider a 240:120-V single-phase transformer. Draw the circuit of the transformer. Include the polarity marks. Label the induced voltages E_1 and E_2, and the currents I_1 and I_2.

    b)   A source voltage of $240\underline{/0}°$ Volts is connected to the primary. A load impedance of $3 + j4\ \Omega$ is connected to the 120-Volt side. Calculate the phasor values of the pri and sec voltages and currents. Verify that the phase angle between V and I is the same (consistent with the PF of the load impedance) on both primary and secondary. Is this a leading or lagging load? How many VA are flowing?

    c)   With load still attached, what is the Thevenin equivalent (V_{OC} and Z_{SC}) looking into the primary of the transformer? (i.e. what does the source "see" as an attached load?) Hint#1: Z in general is defined as ratio of V/I, so you can calculate the apparent impedance "looking into" the primary by dividing V_1 by I_1. Hint#2: Z can be "referred" or "transferred" according the turns ratio squared, i.e. a^2. The turns ratio a is defined in (11.7) - it can be stated in terms of turns or voltage (or current, as I showed in class).

H9.4   The transformer of H9.3 is reconnected as a 360/120 Volt autotransformer (see §11.3). The same load impedance of $3 + j4\ \Omega$ is connected to the 120-Volt side, and a source voltage of $360\underline{/0}°$ Volts is connected to the 360-volt side.

    a)   Draw the circuit. Show polarity marks on coils. Note which coil is the series coil and which is the common coil. Label the currents I_1, I_2, I_S, and I_C. Label the voltages V_1, V_2, V_S, and V_C.

    b)   Calculate the phasor values of the 4 voltages and 4 currents.

    c)   Calculate complex power flowing into the 360-volt terminals, and out of the 120-volt terminals. They should be exactly the same. Are they?

    d)   Calculate the "volt-amp advantage" i.e. for a given transformer, the ratio of VA it can transform as an autotransformer to the VA it can transform as a conventional 2-winding transformer.

    e)   Comment on advantages and disadvantages of autotransformer connection.

H9.5   Problems 11.1, 11.2, 11.3 were done as in-class examples. Review them, make sure you understand them. (You don't have to hand them in).

H9.6   Do Problem 11.9. Refer to §11.5. Do some "simple" circuit analysis for the detailed equivalent circuit for a single-phase transformer.

H9.7   Do Problems 11.11 and 11.12. Comments: Here, with 3-winding transformers, we expand our "what goes in, must come out" concept used up til now for 2-winding transformers, to be more general. Now, with 3 or more windings, it is better to use a more general rule: "the summation of VA flowing into the transformer must be zero." Alternately, since the voltage ratio is equal to the turns ratio, we can also approach this on the magnetic circuit level, saying that "the summation of the MMFs (Ampere-turns) of the transformer coils must be zero" (this is known as Ampere's Law). Polarity marks of the coils and labeling of V polarity and the reference direction of flow of I is essential.