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.

H4.1 - Do problem 4.11 first. 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, $\mu_r$ may be ~8000, so this is actually not a terrible assumption, at least it will not result in large error.

H4.2 Do Problem 4.2 in your text. Add the following parts:

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.

H4.3 Ideal transformers (refer to class notes and §4.5.1 and §4.5.7) pass a given amount of watts and vars through while shifting (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 $240/0^\circ$ 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 (4.30) and (4.31) - it can be stated in terms of turns or voltage (or current, as I showed in class).
H4.4 The transformer of H4.3 is reconnected as a 360/120 Volt autotransformer (see §4.6). The same load impedance of $3 + j4 \Omega$ is connected to the 120-Volt side, and a source voltage of $360/0^\circ$ 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.

H4.5 Do problem 4.15. Refer to handout and Fig. 4.11.

H4.6 Now that you’ve paid your dues in the previous problem (doing the calculation for the detailed equivalent circuit) do problem 4.18 and see how to do it the easy way with a simplified equivalent circuit (usually without introducing much error in the calculation).

H4.7 Do problem 4.21. Main concepts here are losses and efficiency. This is very useful to know what causes the losses and how to calculate the cost of the losses over the lifetime of the transformer. The total effective cost of a transformer is the purchase price PLUS the cost of the electrical losses over its lifetime. Note that “no-load” losses are also called “core losses” and also called “iron losses”. “Load losses” are also called “copper losses.”

Add part d) to this problem:

d) Fill in the blanks: “Copper losses are proportional to ________.” and “Iron losses are proportional to ________.”

Coming attractions: Three phase transformer connections, using wye and delta configurations. If you understand use of polarity marks for single-phase transformer, and if you understand use of voltage phasor diagrams, then it is very straightforward. Homework #5 will be problems 4.31, 4.32, and 4.36, plus a handout problem.