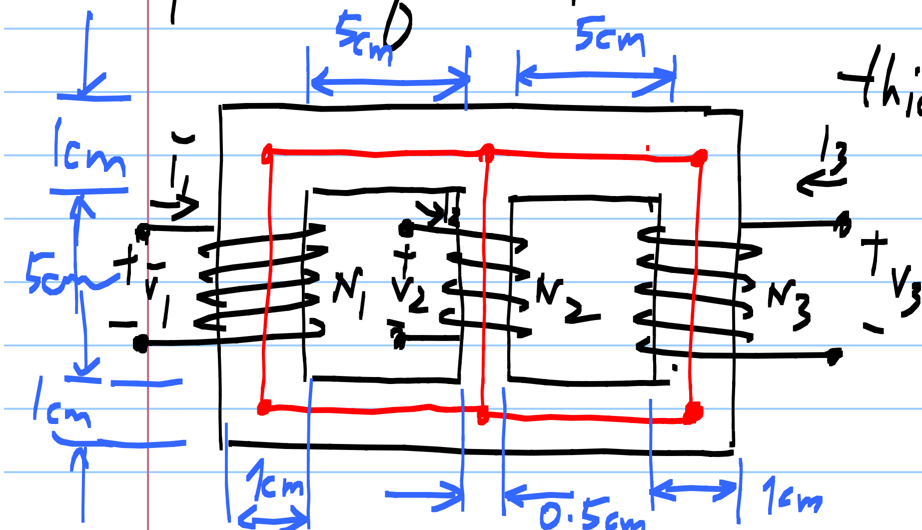
EE1001 Electrical and Magnetic Circuits
Problem set #11 (Due on 28th April 2015)

Note Title 4/10/2012

1. Calculate the self inductance of each coil and the mutual inductance (including the sign (dots)) between each pair of coils. The material has $\mu_r = 1000$ and has a thickness of 1cm everywhere with a square cross section

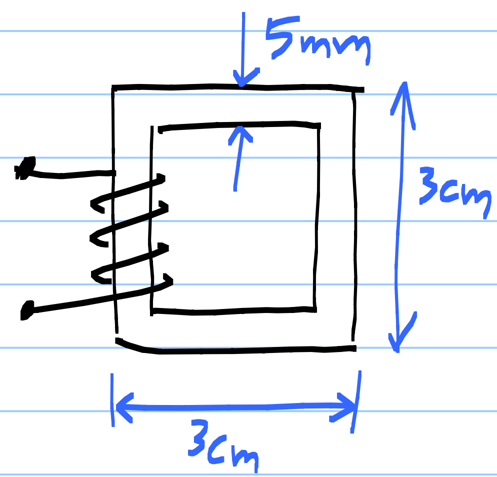


For segment lengths, use the length along the center line (shown in red)

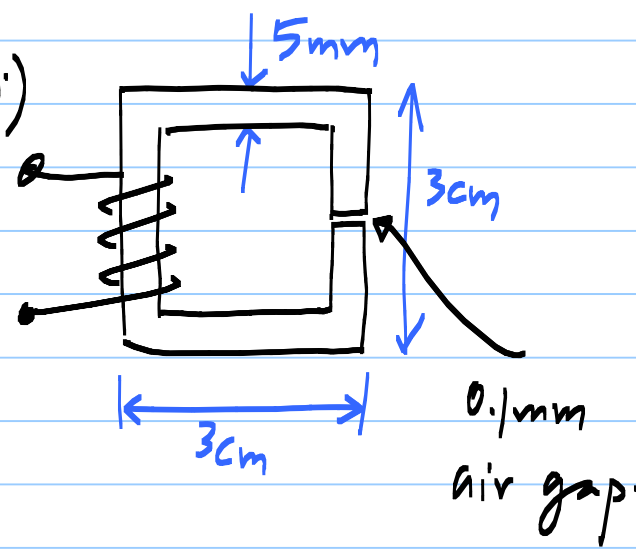
$N_1 = 100$ turns, $N_2 = 50$ turns, $N_3 = 200$ turns

2. You are required to design a 5π mH inductor with a core which has a 5mm × 5mm square cross section. Calculate the number of turns required in the following 3 cases. $\mu_r = 1000$; Segment lengths are along the center line.

(i)



(ii)

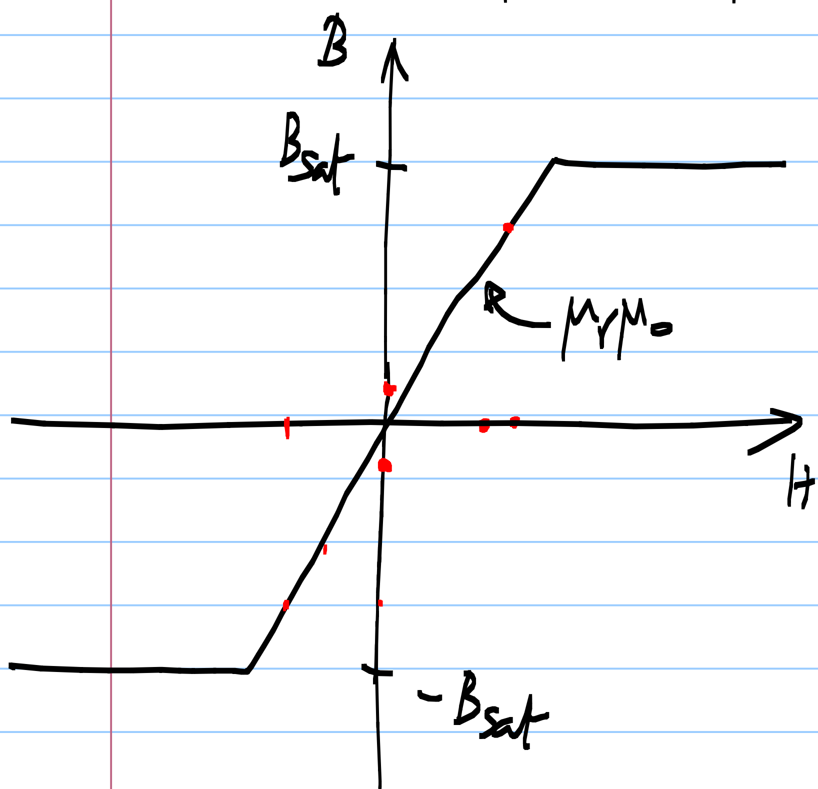


(iii) Single layer air core solenoid.

(assume 0.2mm wire thickness)

(3) The B-H curve of a core material is shown below (idealized for simplicity). In the linear region, $\mu_r = \frac{10^4}{\pi}$.

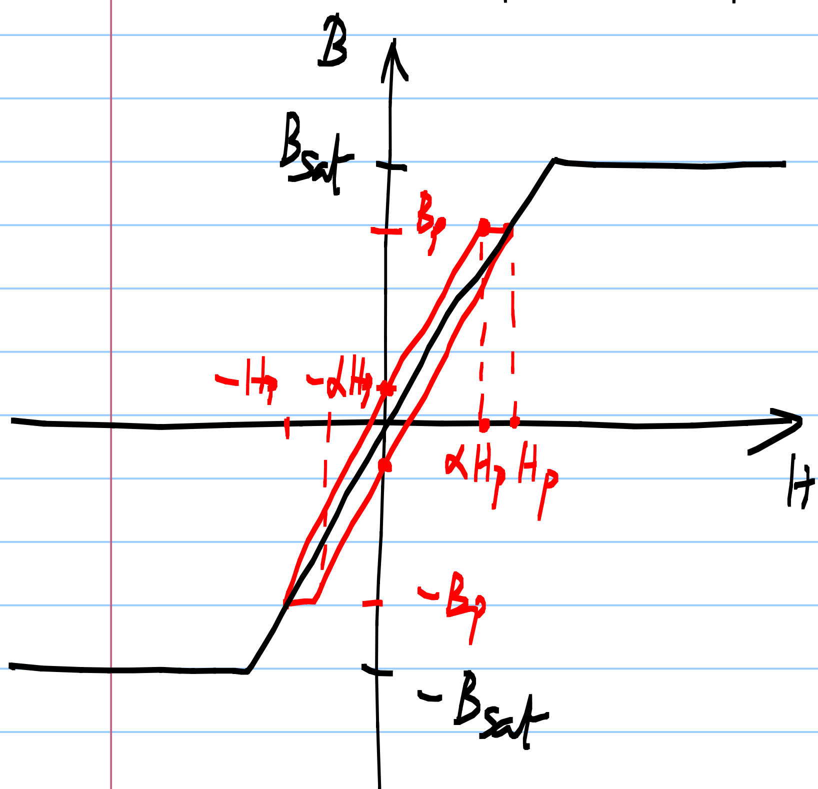
$B_{sat} = 2T$.



(a) Calculate the maximum current I_{max} for the inductors in problems 2(i) & 2(ii)

(b) If you have to redesign the inductor in 2(i) to double its maximum current rating, what should you do?

(4) The B-H curve of a core material is shown below (idealized for simplicity). In the linear region, $\mu_r = \frac{10^4}{\pi}$.



$B_{sat} = 2T$. The hysteresis loop for a peak flux density B_p is shown in red ($B_p < B_{sat}$).

Do the following for the inductors in 2(i) & 2(ii)

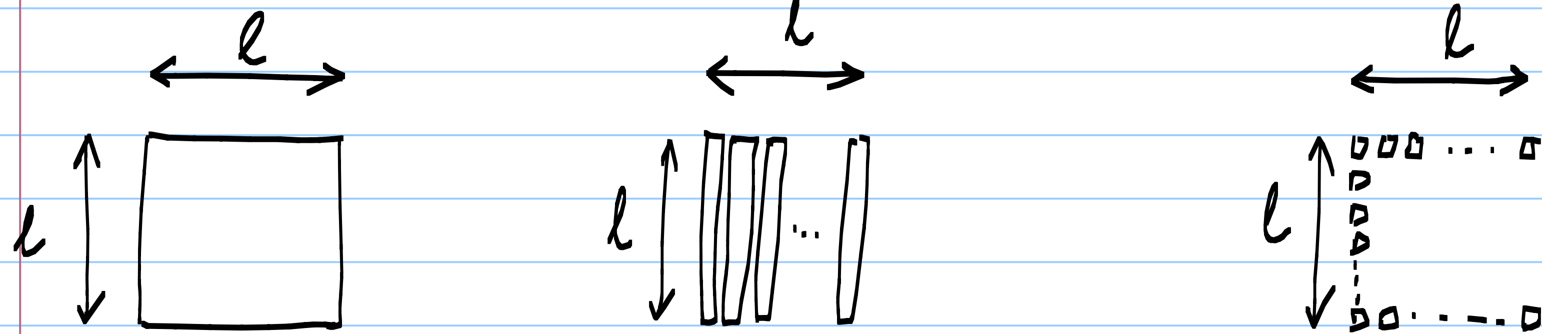
$\alpha = 0.75$. Use I_{max} from p.3

(a) When a sinusoidal current whose peak value equals I_{max} is applied, calculate the peak energy stored, the hysteresis loss per cycle, and the quality factor (use the definition of quality factor in terms of energy: $Q = 2\pi \cdot \frac{\text{Peak Energy stored}}{\text{Energy lost / cycle}}$)

(b) What are the possible ways of improving the quality factor in 2(i)?

(c) Ditto for 2(ii)?

5. Eddy current calculations: Assume that there is a flux density $B_p \sin \omega t$ perpendicular to the loop surfaces. Denote the resistance of the single loop by R. Comment on the loss reduction due to lamination in one and both dimensions

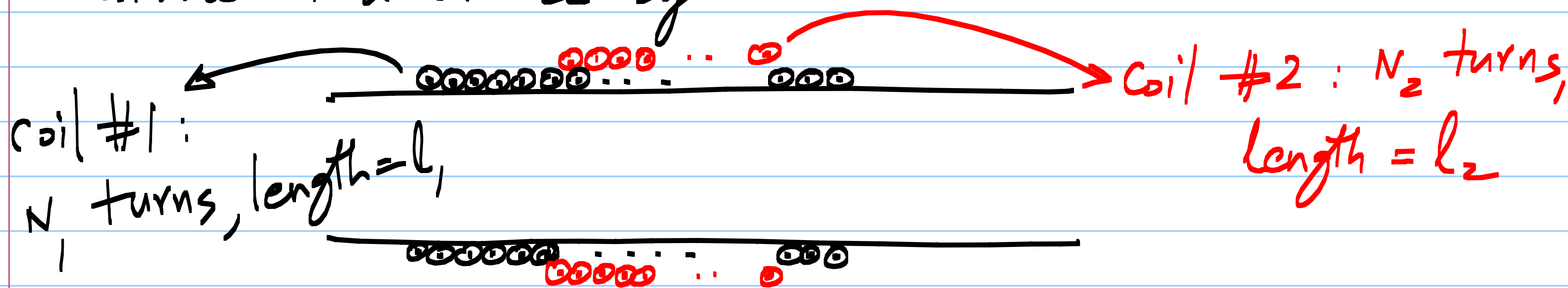


(i) Single loop.

(ii) Sliced in x direction in N_1 loops $(N_1 \gg 1)$

(iii) Sliced in x direction in N_1 pieces & in y direction in N_2 loops $(N_1, N_2 \gg 1)$

6. An air-core mutual inductor is made by winding one solenoid on top of another (assume both have the same cross sectional area). Calculate the mutual inductance by



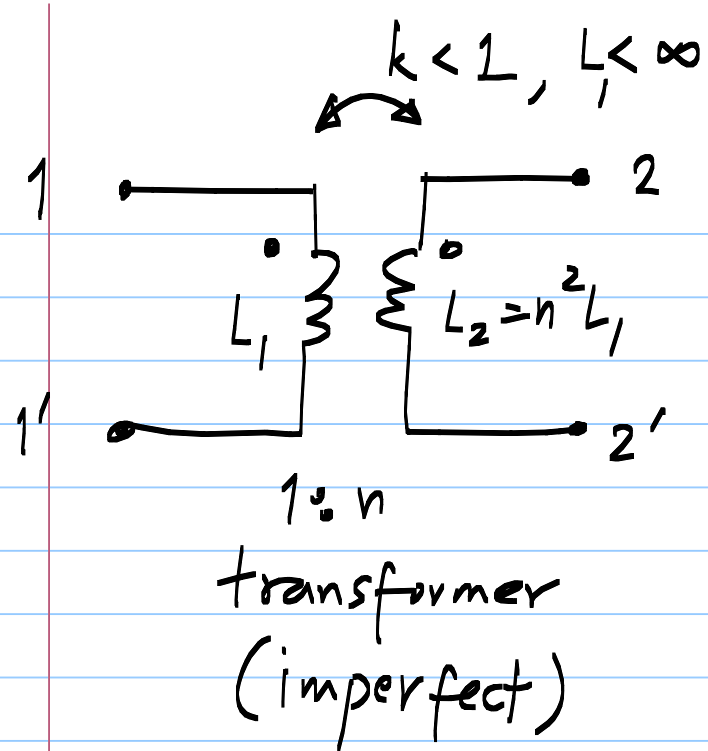
(i) Passing a current i_1 through coil #1 and finding the voltage induced in coil #2

(ii) Passing a current i_2 through coil #2 and finding the voltage induced in coil #1

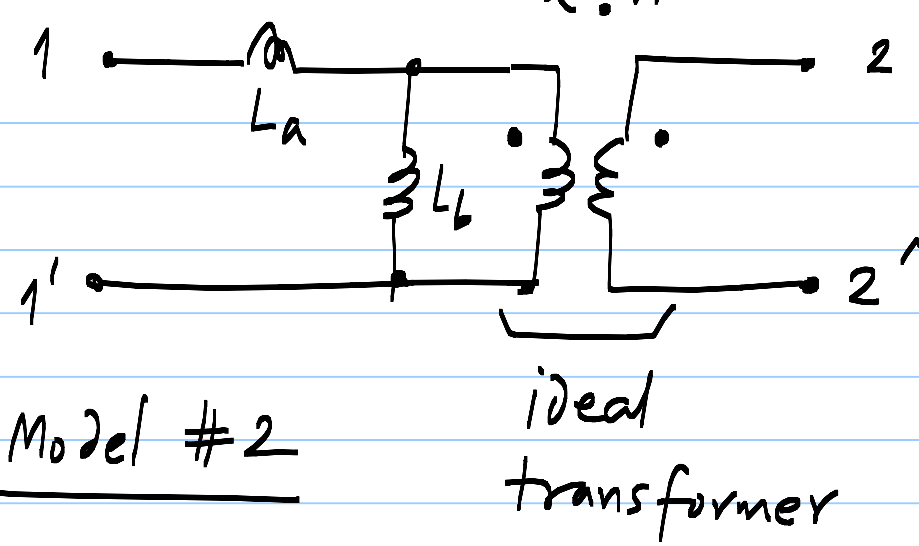
[Note: both (i) & (ii) should yield the same mutual inductance. If not see where you have gone wrong & reconcile. All the usual solenoid assumptions apply]

(iii) Calculate the coupling coefficient k. When is this maximum? What is the maximum value?

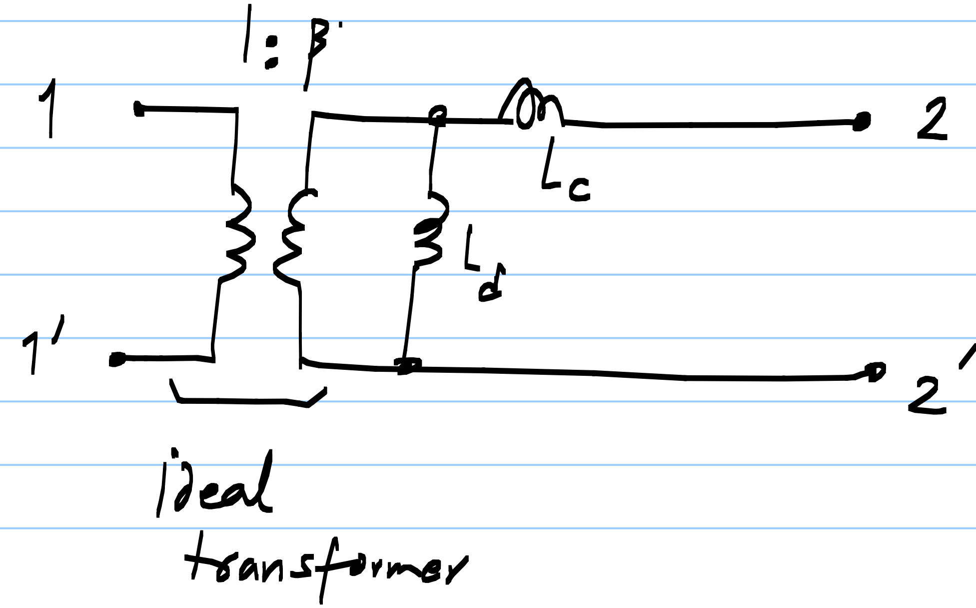
(7) A pair of mutually coupled inductors have inductances L_1, $L_2 = n^2 L_1$ (L_1 finite) and a coupling coefficient k ($k < 1$). Calculate the parameters in the following models so that they are equivalent to the imperfect $1:n$ transformer.



Model #1



Model #2



(8). An antenna at 2.4GHz used for Wi-Fi receivers can be modeled as a sinusoidal source in series with a 50Ω resistance. The receiver itself can be modeled as a 200Ω resistive load. You need to achieve maximum power transfer to the load.

(i) Assuming you use an ideal transformer to match the load to the source, what is the turns ratio you need?

(ii) If the inductances are finite, what is the minimum primary (source side) inductance required so that the magnitude of the load voltage is only 1% different from the ideal case?