EE 340L – Experiment 3: Magnetic Circuits

Real-world inductors made of physical components exhibit more than just a pure inductance when present in an AC circuit. A common circuit simulator model of an inductor is shown in Fig. 1 below. It includes the actual ideal inductor L with a parallel resistive component R_c that responds to alternating current (i.e., represents losses in the core material due to eddy currents and hysteresis), a resistive component R_{cu} in series with the ideal inductor (i.e., resistance of the copper coil), and a capacitor C that is connected across the entire assembly and represents the capacitance present due to the proximity of the coil windings. At low frequency such as 60 Hz, the latter capacitance is very small, thus can be ignored.

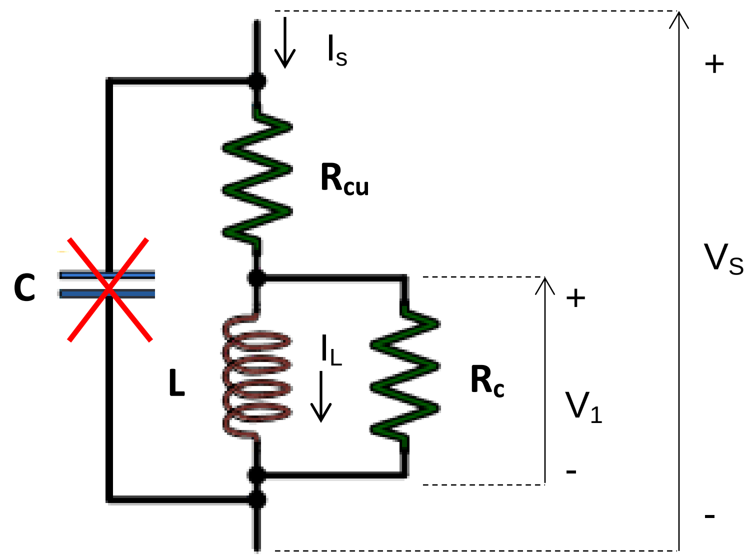

Fig. 1

When a DC voltage V_{DC} is applied across the inductor, the core loss resistance is infinite, the ideal inductor is a short circuit, and the inter-winding capacitor is an open circuit. Hence, the practical inductor appears as a resistance that corresponds to that of the copper wire. Then Rcu can be obtained by simply dividing V_{DC} by the resulting current I_{DC}.

$$R_{cu} = \frac{V_{DC}}{I_{DC}}$$

In an AC voltage V_s is applied across the inductor, let I_s be the resulting current, P and Q be the resulting real and reactive powers supplied by the source, and θ be the power factor angle. Ideally, this angle should be equal to 90^o, but in practice, it is below this value.

The voltage V_1 across the ideal inductor and core loss resistance can be computed by

$$V_1\angle\delta = V_s\angle 0 - R_{cu} I_s \angle -\theta,$$

The value of L and R_c can then be computed as follows:

$$L = \frac{V_1^2}{\omega Q}, \qquad R_c = \frac{V_1^2}{P - I^2 R_{cu}},$$

The rms current I_L through the ideal inductor simply found by dividing V_1 by ωL.

What follows is an experiment to determine the equivalent circuit parameters (R_{cu}, L, R_c) of the 1200Ω inductive reactor in the Power Laboratory.

1. Connect a variable DC supply across the 1200Ω inductive reactance, wire the circuit to record the voltage and current. Turn on the supply and increase the voltage slowly till you reach a current of 100 mA. Record the corresponding voltage, then determine R_{cu}. Alternatively, one can measure this resistance by simply connecting an Ohm-meter across this inductor.

VDC = …….. V

IDC = 0.1 A

Rcu = ……… Ω

2. Connect 120 V (AC) across the inductor and measure the current, real and reactive powers. You can also record the voltage and current waveforms by using the scope mode of the Data Acquisition System. Use the above equations to determine the values of L and R_c.

V = 120 V

I = ….   A

V1 = ……… V

P = ………… W

Q = ………. VAR

L = …….. H

Rc = ……… Ω

I_L = …….   A

The picture in Fig. 2 below shows an image of the actual reactor analyzed above. The number of turns N is unknown, while the shell-type core material is made up of cast steel. The dimensions of the core are shown in the figure to the right. The shell-type core and be converted to an equivalent rectangular core with the following parameters: cross section area A= 5×10^{-4} m^2, average length of flux path: l =0.14 m.

Relation of peak flux density to peak value of applied voltage: $\hat{B} = \frac{\hat{\phi}}{A} = \frac{\hat{V}}{\omega N A}$

Relation of peak flux intensity to peak value of inductor current: $\hat{H} = \frac{N\hat{I}_L}{l}$

Relation of coil inductance to core permeability: $L = \frac{N^2 \mu A}{l}$

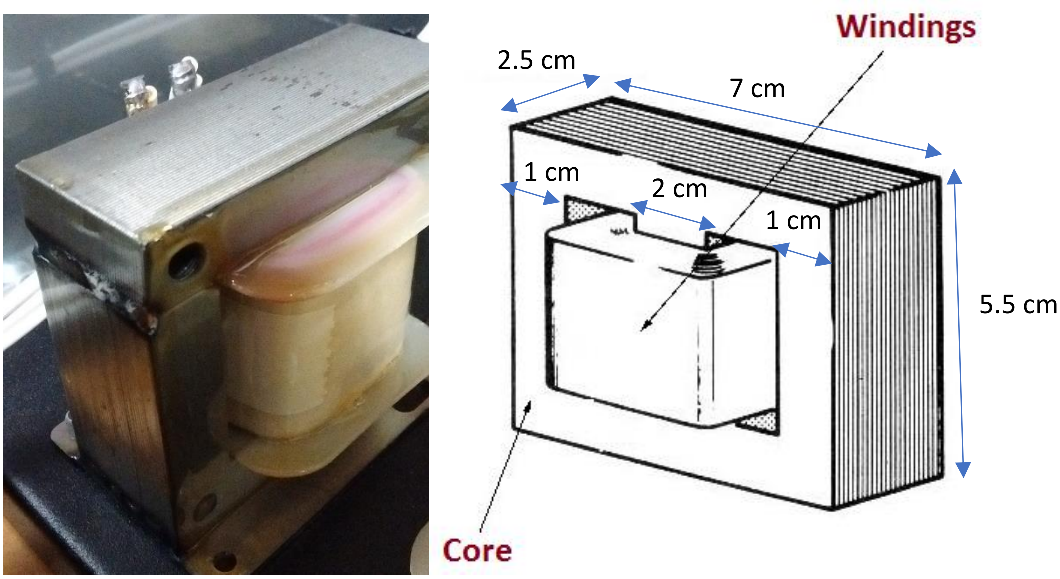

Fig. 2

Try different values of N till the peak value of B and peak value of H fall on the B-H curve of cast steel (see graph in Figure 3 below), then determine the corresponding value of μ, and value of the inductance. Compare this latter to the one calculated above.

N = …..

B (peak) = ………. T

H (peak) = ……… A/m

μ = ……… H/m

L = ……… H

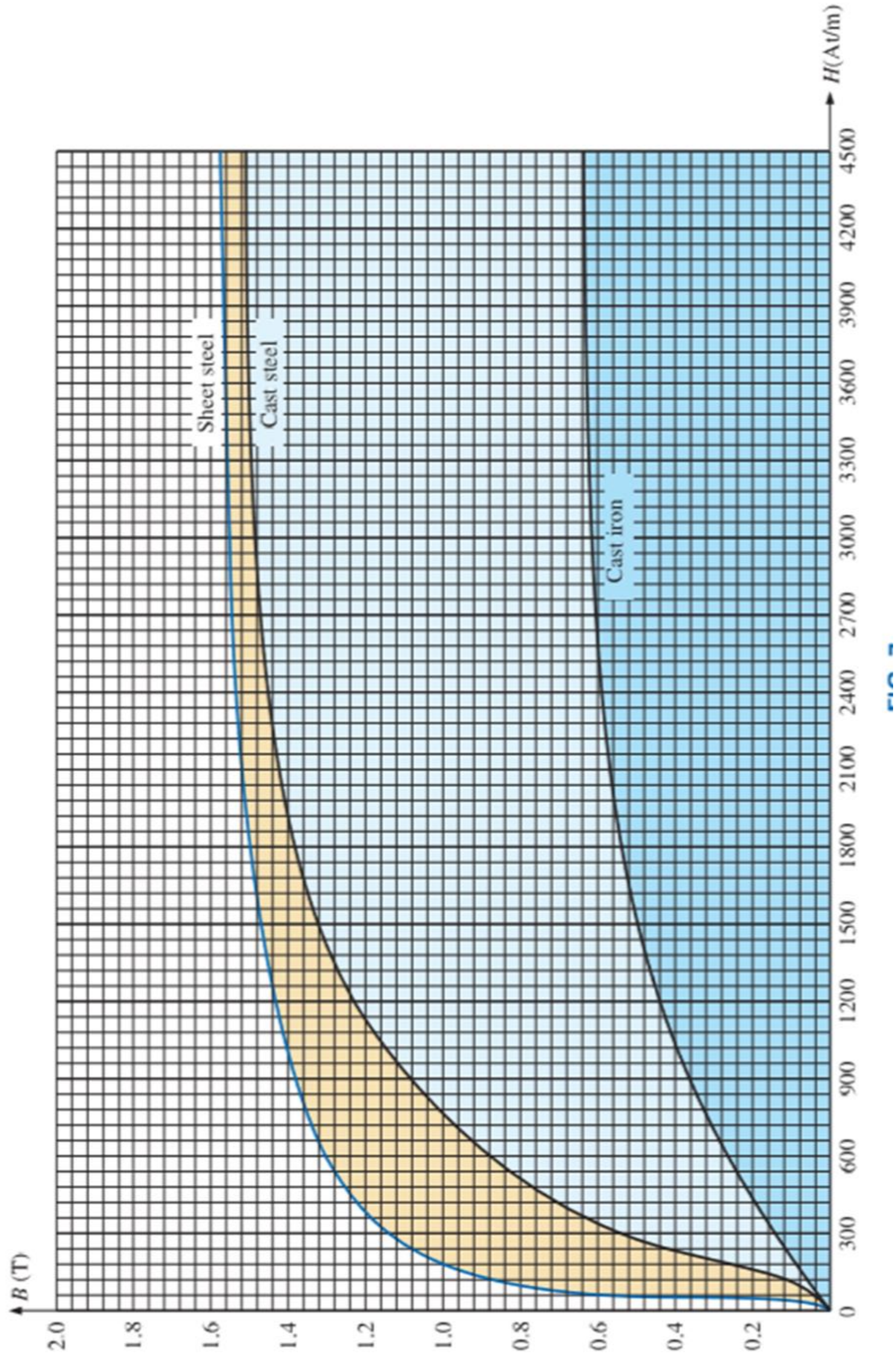
B (T)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
300
600
900
1200
1500
1800
2100
2400
2700
3000
3300
3600
3900
4200
4500
H (At/m)
Sheet steel
Cast steel
Cast iron

Fig. 3