Mutual & Self Induction Lab Activity

1. <u>Probe coil Self Inductance (Theory)</u>: Measure, calculate, report:
(a) Measure inner and outer radius ("a" and "b") with uncertainties
(b) Calculate the average radius "r" from "a" and "b".
(c) Measure the "height" of the coil ("h").
(d) How many turns in the coil? (N)
(e) Calculate the theoretical "self-inductance" in units of Henries: $L = \frac{\mu_0 N^2 \pi r^2}{h}$

2. <u>RL Circuit Time Constant</u>: Similar to our "capacitor" lab, measure the Time Constant for the decay of an RL circuit. One of the problems is that the total resistance of the circuit must include that of the signal generator, the coil and the externally added resistor. The signal generator should be set for square wave output. On the oscilloscope, either measure across decade resistor or across the inductor, whichever works best for you.
(a) Explain briefly which method you used for your measurement.
(b) Draw the waveform you used to measure the time constant, showing your measurements.
(c) What is the measured time constant? Include uncertainties.
(d) What is the value of the external resistor you used (decade box)?

3. <u>Measured Value of Inductance (from time constant)</u>:
Recall the time constant is related to the inductance: τ=L/R
(a) What is the Resistance of the Signal Generator? (printed on front!)
(b) What is the internal resistance of the coil? (measure with ohm meter)
(c) What is the value of resistance you added to the circuit with the decade box "R_d"?
(d) What hence is the total resistance of the circuit "R" ?
(e) Calculate your measured inductance (from the time constant and resistance).

4. <u>AC Reactance Inductor</u>
Set the signal generator for sine wave output. The oscilloscope measures the voltage across the inductor (so you can measure the peak to peak voltage). Use a multimeter to measure the voltage across the "shunt" resistor (role played by the decade box, set for perhaps 300 ohms or greater as needed to make a good picture).

- You will make measurements at least 5 frequencies (above and below 1000 Hertz), which show significant variation in the reactance.
- Measure (peak to peak?) voltage "V_L" across inductor on oscilloscope
- Measure (rms ?) voltage "V_R" across resistor with multimeter (set to AC volts)
- Calculate the peak-peak current: $I_{pp} = 2\sqrt{2}\, I_{rms}$, where $I_{rms} = V_R / R_d$
- Calculate the reactance (Voltage across inductor divided by current in inductor)

DATA

Frequency f (Hertz)	Waveform	V_L	V_R	Current $I=V_R/R_d$	Reactance $X=V_L/I$
100	sine				
500	sine				
1000	sine				
5000	sine				
10000	sine				

- **Plot**: Squared Reactance versus squared frequency. Hopefully it will be a line.
- **Analysis:** Fit the graph with a line, get slope and intercept.

Question 4:
(a) Is your plot a line as we hoped? (What is the statistical R-squared value?)
(b) The intercept should be the (squared) value of the resistance of the inductor. Is this approximately correct?
(c) The slope should be equal to $[2\pi L]^2$. From the slope, extract the value of the inductance.

Question 5: Comparison
(a) Compare your measured value of inductance from 3e and 4c. Are they close?
(b) Compare these measured values of inductance with your theoretical calculation from 1e.

6. Large Coil: Measure, calculate, report:
(a) Measure inner and outer radius ("a" and "b") with uncertainties
(b) Calculate the average radius "r_1" from "a" and "b".
(d) How many turns in the coil? (N_1)
(e) Calculate the theoretical mutual inductance: $M = \frac{\mu_0 N_1 N_2 \pi r_2^{\,2}}{2r_1}$ (note the "2" values are the small probe coil, the "1" values are the large coil.

7. Measure Mutual Inductance
Set the signal generator for sine wave output. Connect it in series with the large coil and with a decade resistor box. On channel 1, display the voltage across the decade resistor (hence it's a measurement of the current in the inductor). On channel 2, display the voltage across the small coil

- You will make measurements at least 5 frequencies (above and below 1000 Hertz).
- For each measurement, calculate the input current (voltage across decade resistor divided by the decade resistance): $I = \frac{V_R}{R_D}$
- For each measurement calculate the mutual inductance: $M = \frac{V_2}{2\pi f I}$

DATA

Frequency	Waveform	V_R	V_2	Current $I=V_R/R_D$	M
100	sine				
500	sine				
1000	sine				
5000	sine				
10000	sine				

Question 7. Compare
(a) Are your mutual inductance measurements approximately constant?
(b) What is the average of your measured mutual inductance?
(c) Compare your measured value with the theoretical one calculated in question 6e.