Lab 7: Magnetic Induction

In this lab, you'll be creating a time-varying magnetic field, and measuring the magnetic induction between two solenoids. Unlike other labs, there's not a lot of repetitive data-collection and detailed analysis in this one, just some simple measurements. As a result, I'd like you to answer the **boldface questions** in lab, performing any necessary calculations.

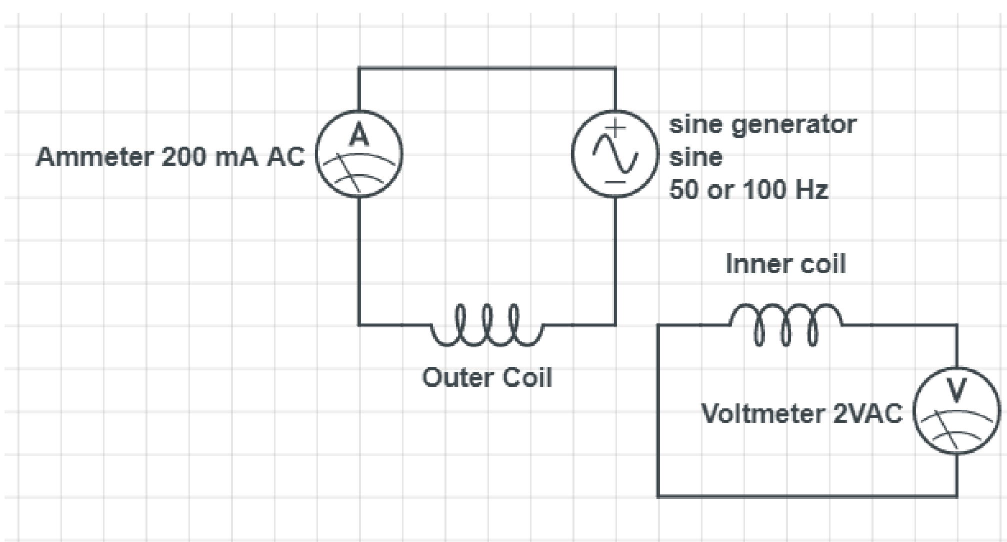
1. Equipment:

Outer coil: 2920 turn solenoid, 11 cm long, 3.5 cm diameter
Inner coil: 235 turn solenoid, 1.5 cm diameter

Sine wave generator
Current meter (200 mA alternating current)
Volt meter (2 V alternating current)
Labpro Magnetic field sensor (set to 6.4 mT range)
Laptop

2. Setup

Set up the apparatus like this:

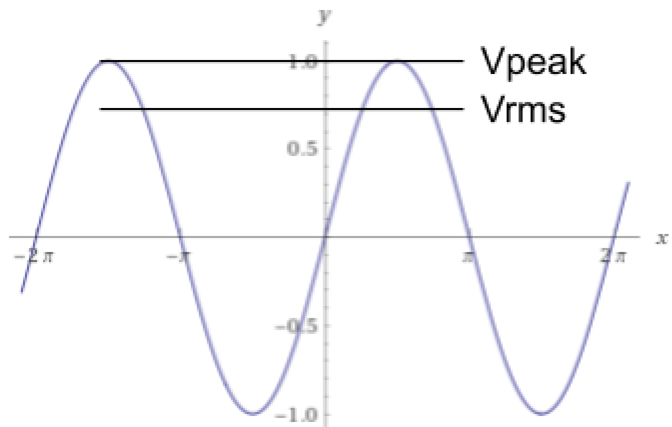


3. Measuring the magnetic field

Set up the Labpro magnetic field sensor. Set the field range to 6.4 milliTesla, start up Logger Pro, and choose the Experiment / Data Collection menu item. Set Logger Pro to collect data 1000 times a second, for 0.1 seconds. Leave the inner coil outside of the outer coil for now. Stick the magnetic field probe inside the outer coil.

Turn on the sine wave generator to a frequency of 50 Hz and a moderate amplitude, and stick the Labpro magnetic field sensor inside the outer coil. **Record the AC current flowing**

through the coil, and the amplitude of the magnetic field. **Repeat** your measurements at a frequency of 100 Hz: adjust the amplitude knob to get the same current as before.

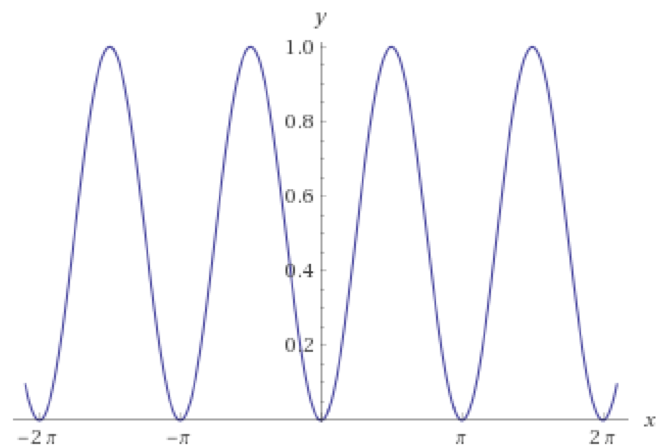


4. A note on AC amplitudes

In most areas of physics, the strength of a sinusoidal signal is measured using the amplitude, the distance from zero to the peak of the sine wave. However, in electrical engineering the RMS (root-mean-square) strength is used.

If $V(t) = A \sin \omega t$, then the RMS voltage is calculated by squaring, then averaging, then square-rooting.

$$V_{RMS} = \sqrt{mean(V^2(t))}$$



The graph at lower right shows what $A^2 \sin^2 \omega t$ looks like. Clearly, $mean(A^2 \sin^2 \omega t) = \frac{1}{2} A^2$. Thus, after taking the square root, the RMS voltage is just:

$$V_{RMS} = A / \sqrt{2}$$

Your multimeters measure RMS current and voltage, but with the magnetic field sensor, it's probably easiest to measure amplitude.

You can do your calculations and report your results using either amplitude or RMS, but you must be consistent throughout, and should **explain which you're using in your writeup.**

5. Magnetic Field Strength: Theory vs Measurement

Use the results from lecture or the book to **calculate the expected magnetic field strength inside the outer solenoid**. **Compare this theoretical value with the measurement you made in Step 3.**

6. Induced Current

Now, gradually insert the inner coil inside the outer one. **Describe how the voltage on the inner coil changes** as you do so. Notice that a voltage can be induced even when the coils are not physically touching!

With the inner coil fully inserted, **measure the induced voltage on the inner coil and the current flowing through the outer coil at a frequency of 50 Hz.** Then, increase the driving frequency to 100 Hz, adjust the outer coil current so it's the same as before, and **repeat the measurement.** You should see a higher voltage than before: **explain why**.

7. Induced voltage: Theory vs Measurement

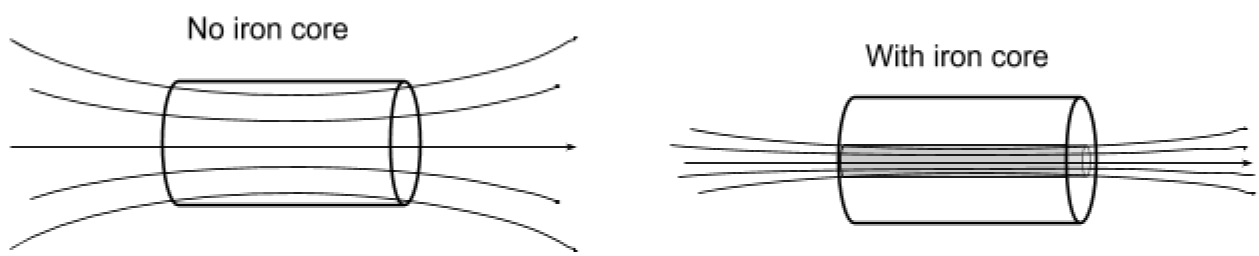
Use the results from Step 5 to calculate the expected EMF (voltage) induced in the inner coil. Don't forget the inner coil has 235 turns! **Compare your results with the measurements made in Step 6.**

8. Mutual inductance

Calculate the mutual inductance M of this 2-coil arrangement, in SI units (Henries). This value should be independent of frequency: you should get roughly the same number at 50 vs 100 Hz.

9. Goofing around:

a) Try sticking the metal rod inside the inner coil. What happens to the voltage induced in the inner coil? Iron and other ferrous metals *pull magnetic field lines into them*, as shown in the diagram below. There's a whole chapter on magnetic fields in materials in the book that we don't have time for. :(



b) You should be able to get an induced voltage reading from the inner coil even when it's completely outside the outer coil. How far away can you go and still get a response? (Watch out for spurious signals. Do a controlled experiment!)