

DEPARTMENT OF ELECTRICAL, ELECTRONIC AND COMPUTER ENGINEERING

ANTENNAS AND MICROWAVES
EMZ 320

PRACTICAL 1 REPORT: LENZ'S LAW

2012-08-17

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Table of Contents

0. Plagiarism Statement i
1. Introduction 1
2. Aim 1
3. Theoretical Preperation 1
4. Experimental Setup 2
5. Experimental Procedure 3
6. Experimental Results 4
7. Conclusion 7
8. References 8

1. Introduction

It is generally assumed that measuring a voltage difference between two points will always result in the same value. However, as shall be shown, when these voltages are measured on a closed loop in the presence of time varying magnetic and electric fields this assumption no longer holds true.

2. Aim

By studying the properties that a stationary closed loop exhibits in the presence of a time-varying electromagnetic field the phenomenon will be explained.

3. Theoretical Preparation

The theoretical preparation for this experiment involves doing the calculations that follow. Firstly the two measurements in effect can be seen as in the figure below. The circuit diagram on the left of figure 1 represents method A and the circuit diagram on the right represents method B, which will be elaborated on in the Experimental procedure section.

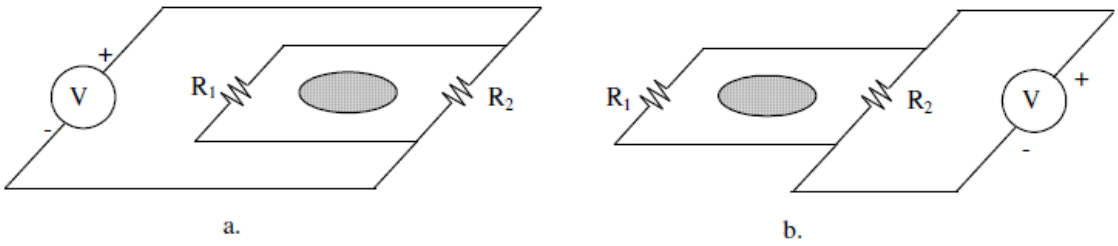


Figure 1: Experiment setup configuration

For method A the calculations are as follows. Firstly the transformer emf is calculated, the value of the time varying magnetic field must be known.

$$V_{emf}^{tr} = \int \frac{d\boldsymbol{B}}{dt} d\boldsymbol{s}$$

Kirchhoff's Voltage Law (KVL) is then used around the loop in figure 2 to yield the following equation.

$$IR_1 + IR_2 = V_{emf}$$

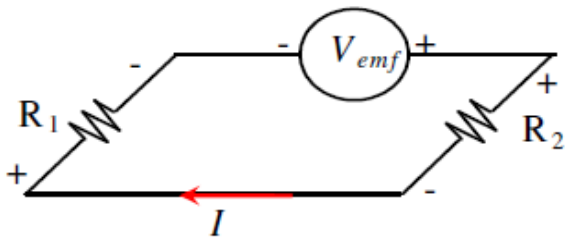


Figure 2: Equivalent circuit for Figure 1 diagram a.

Solving that equation for the current, I, and then substituting into the equation below which is derived from figure 3.

$$V - IR_1 = 0$$

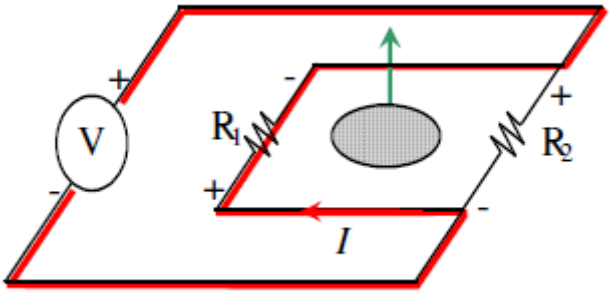


Figure 3: Current path around circuit for method A

All that is now left to do is solve for the voltage V. This method followed is not the only way in which this problem can be solved, the same applies for the method B calculations.

Next the method B calculations are looked at. A similar approach to that followed above is used. The current remains unchanged from the above calculations. Then derived from figure 4 is the following equation which is solved for the voltage V.

$$-V - IR_1 = -V_{emf}$$

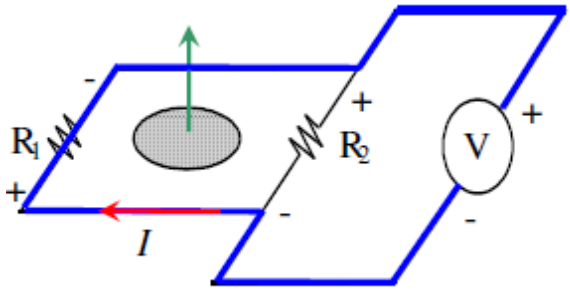


Figure 4: Current path around circuit for method B

4. Experimental Setup

A magnetic ferrite core, which has a high permeability, is where the magnetic flux will be generated. A resistive loop consisting of two resistors, R1 and R2 that are in series, is coiled around the one end and the signal generator is connected to coils on the opposite end of the ferrite core as shown in figure 1. The voltage across the resistor is then measured at the same points while using different configurations, as can be seen in figures 2 and 3.

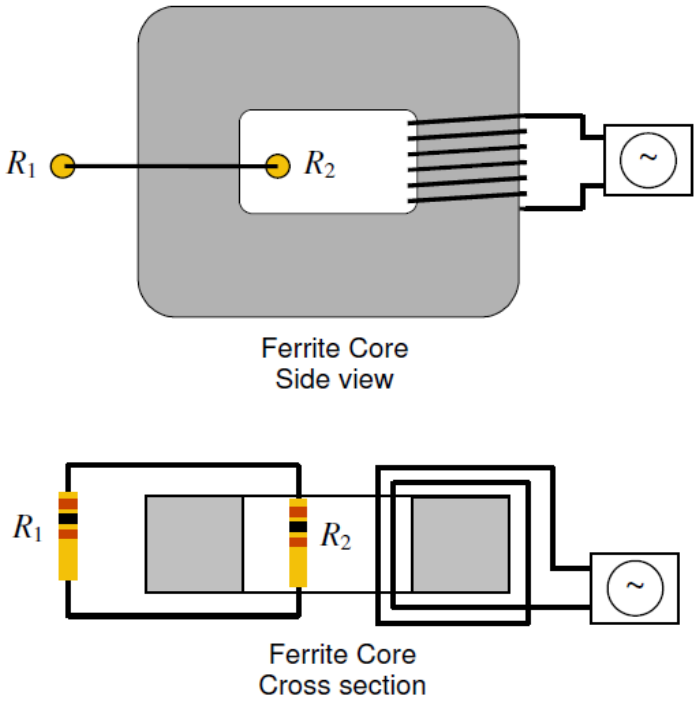


Figure 5: Experimental setup

5. Experimental Procedure

The signal generator was set up to generate a 200 kHz sinusoidal signal which is used to generate a time varying magnetic flux in the ferrite core. Firstly the resistor values of R1 and R2 where chosen as 100 Ù. Measurements were then taken with the oscilliscope probes connected as shown in figure 2, this will be reffered to as Method A. This being the reference measurement. The oscilliscope probes were then connected as in figure 3, this will be reffered to as Method B, and measurements were taken again. The measurements taken included the amplitude and phase of the waveforms. The only difference between method A and method B being the fact that in method B the oscilliscope probe goes throught the ferrite core whereas in method A it does not.

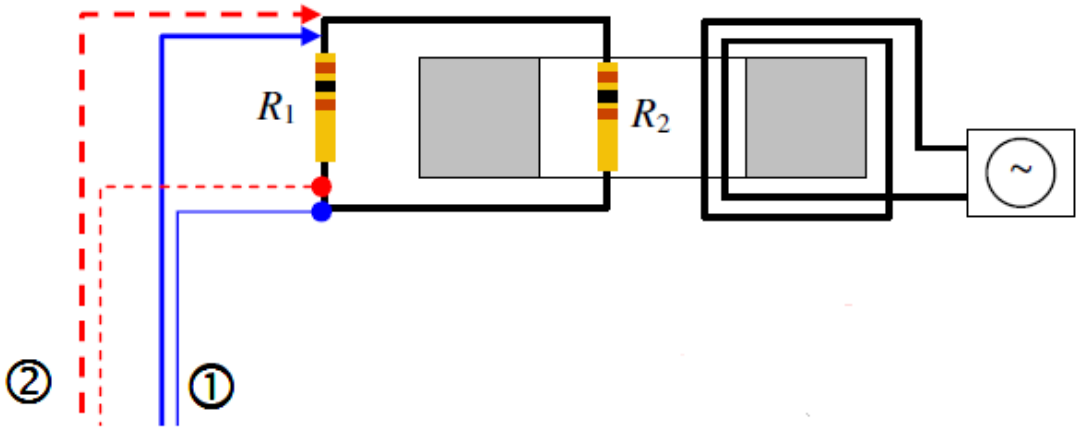


Figure 6: Method A measurement setup

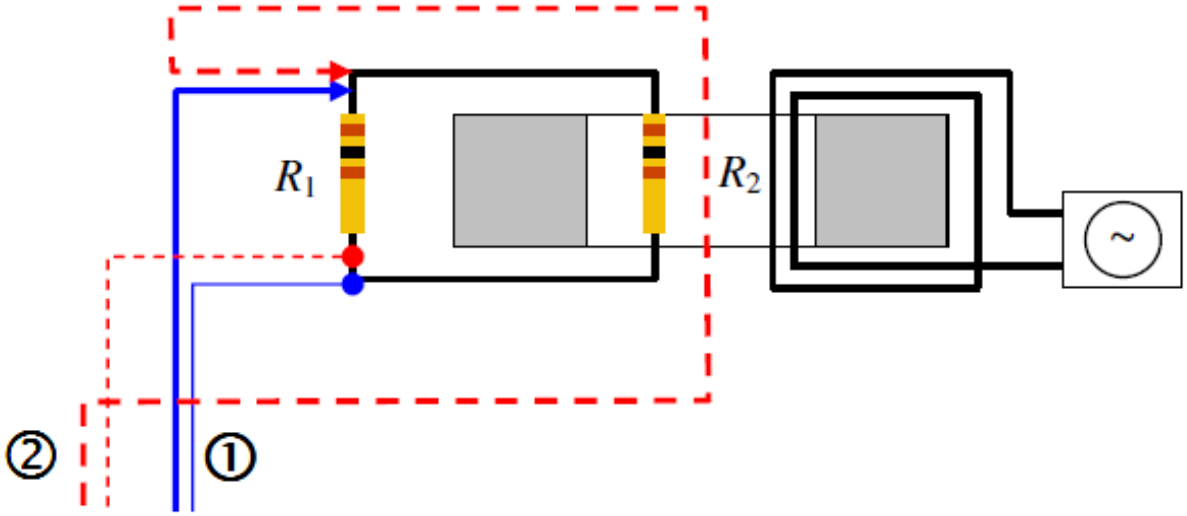


Figure 7: Method B measurement setup

It can be noted that this setup in effect represents a step down transformer as the results will show. This process was then repeated with a new value of R2. The value for R2 was chosen as 10R1 = 1000 Ω.

6. Experimental Results

The results that were obtained are summarized, for each different method, below in a table for the different resistor values used. All values for voltage amplitude given below are peak to peak values.

Firstly the results from method A and method B with both resistor values equal to 100 Ω are shown. The voltage amplitude of the signal generator is 15 V.

Table 1: Measurements from method A and Method B with R1 = R2

Resistor Values	R1 = R2 = 100 Ω			
Method	A		B	
Probe Number	1	2	1	2
Voltage Amplitude	31.6 mV	31.6 mV	31.6 mV	39.6 mV
Voltage Ration	1:1		1:0.798	
Phase Difference	0°		180°	

The figure below shows the signal generator voltage amplitude and Probe 2 voltage amplitude in the configuration of method A. The top waveform represents the signal generator and the bottom waveform represents the measurement across the resistor.

The figure that follows figure 8 shows the signal generator voltage amplitude and Probe 2 voltage amplitude in the configuration of method B. The top waveform represents the signal generator and the bottom waveform represents the measurement across the resistor.

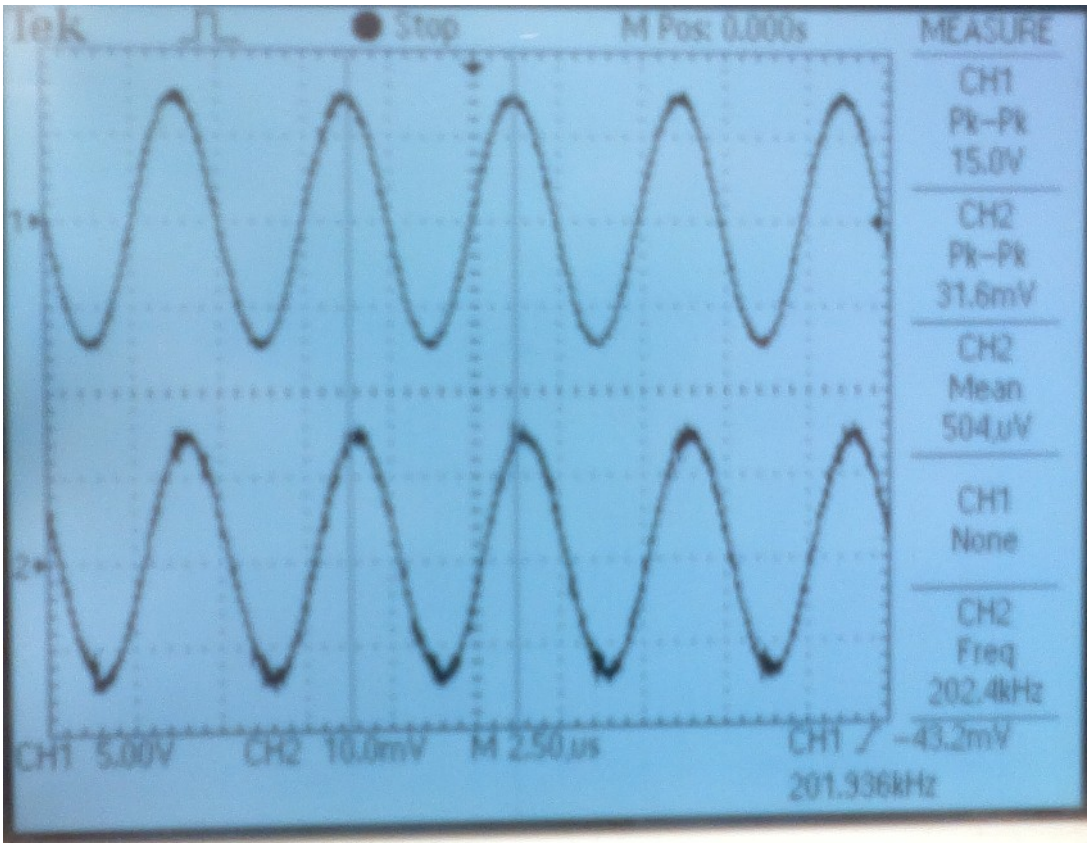


Figure 8: Signal generator voltage amplitude and Probe 2 voltage amplitude for method A

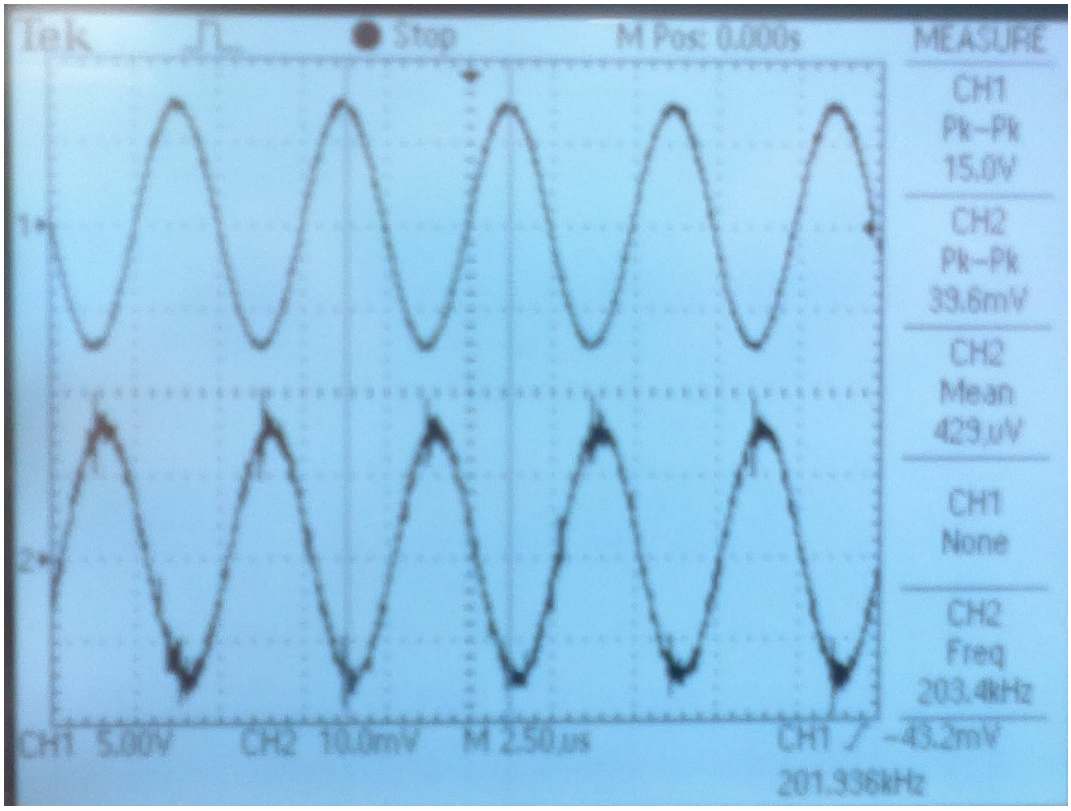


Figure 9: Signal generator voltage amplitude and Probe 2 voltage amplitude for method B

Comparison of the bottom waveforms of figures 4 and 5 one will notice that they are 180° out of phase, this was confirmed via measurement.

Secondly the results from method A and method B with differenct resistor values for resistors R1 and R2 are shown, the voltage of the signal generator remained at 15 V.

Table 2: Measurements from method A and Method B with R1 ≠ R2

Resistor Values	R1 = 100 Ω; R2 = 1000 Ω			
Method	A		B	
Probe Number	1	2	1	2
Voltage Amplitude	8.48 mV	8.48 mV	8.48 mV	62.4 mV
Voltage Ration	1:1		1:0.136	
Phase Difference	0°		195°	

The figure below shows the signal generator voltage amplitude and Probe 2 voltage amplitude in the configuration of method A. The top waveform represents the signal generator and the bottom waveform represents the measurement across the resistor.

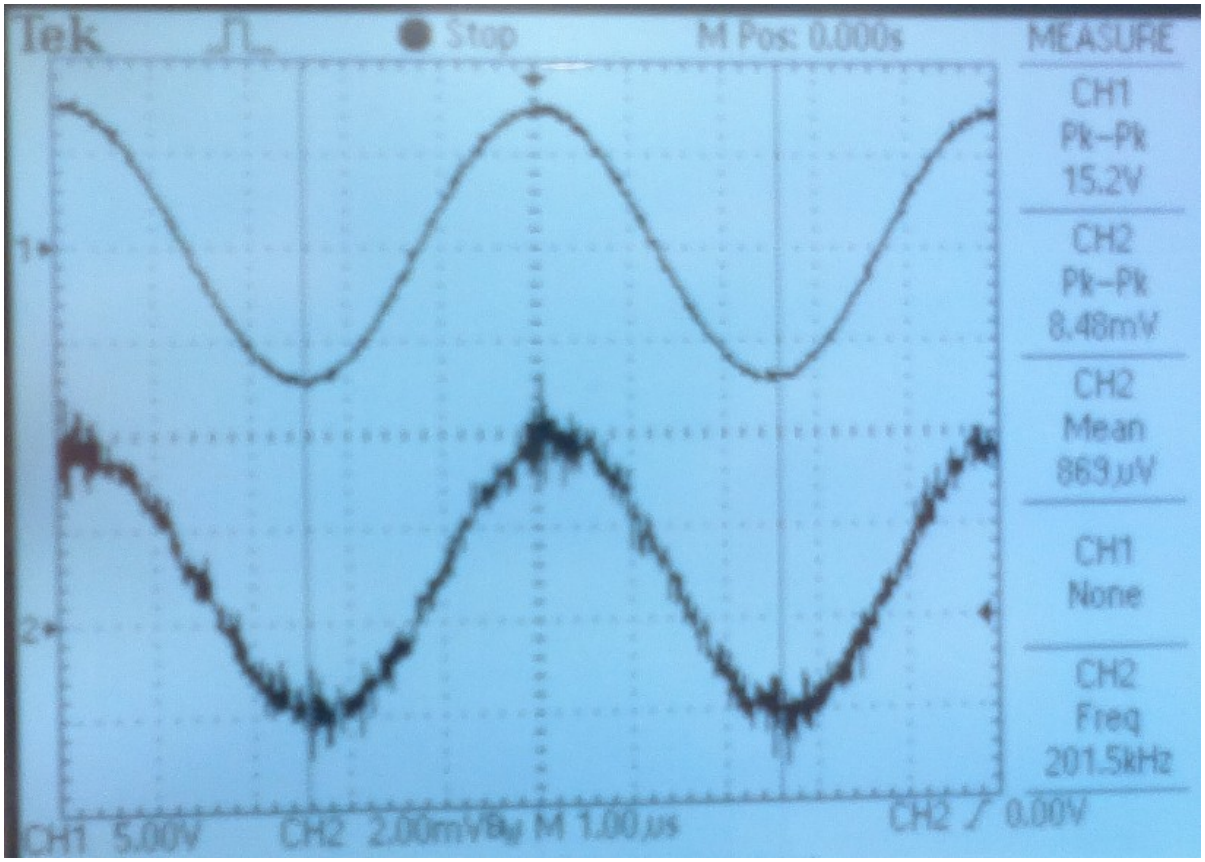


Figure 10: Signal generator voltage amplitude and Probe 2 voltage amplitude for method A

The figure below shows the signal generator voltage amplitude and Probe 2 voltage amplitude in the configuration of method B. The top waveform represents the signal generator and the bottom waveform represents the measurement across the resistor.

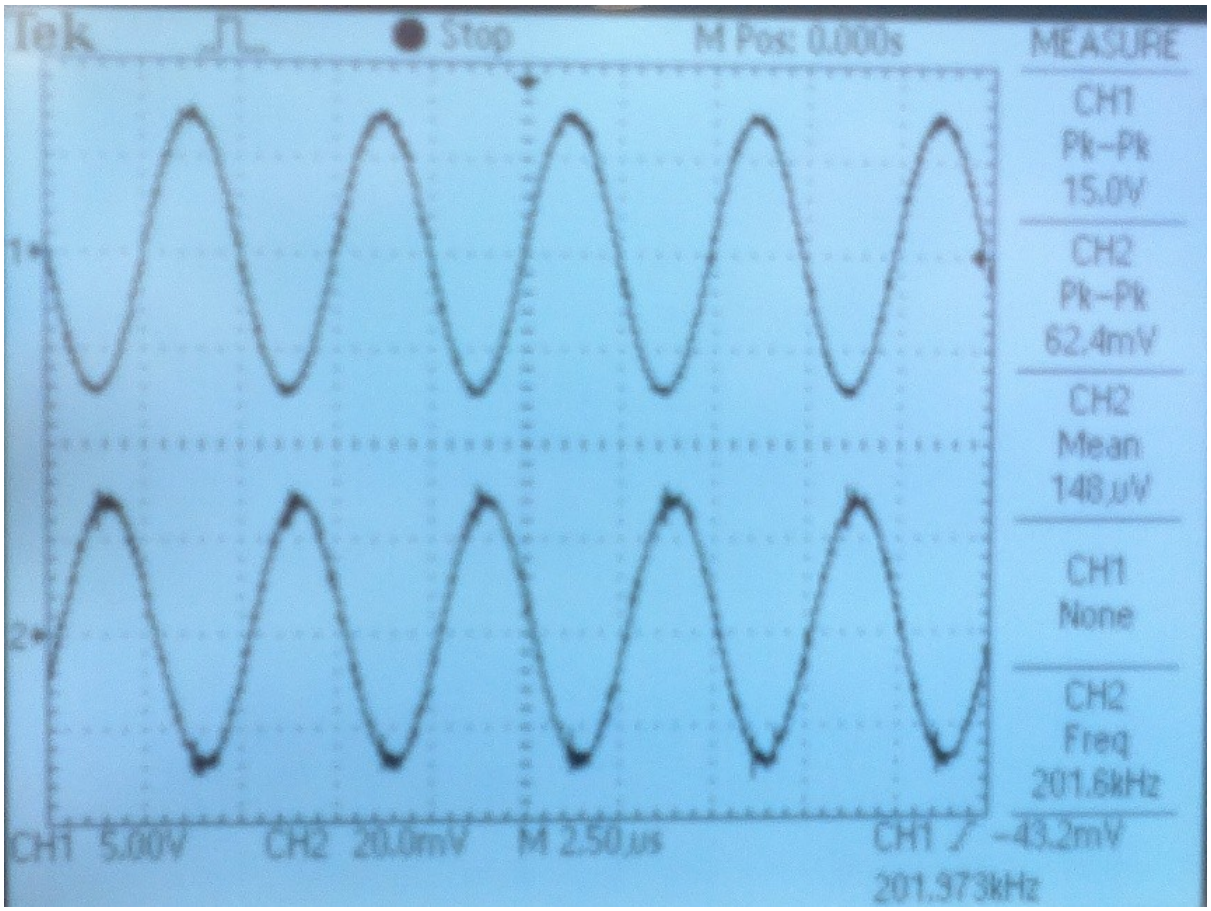


Figure 11: Signal generator voltage amplitude and Probe 2 voltage amplitude for method B

Comparison of the bottom waveforms of figures 6 and 7 one will notice that they are approximately 180° out of phase, the actual phase difference however is 195° as was measured.

7. Conclusion

As was expected the voltage readings from method A and B differed from each other. In effect the voltage measurement from method A can be seen as a voltage measurement across the resistor R1, evident from figure 1 diagram a. Method B is then in effect the voltage measurement across resistor R2, evident from figure 1 diagram b. The reason for method B's measurement yielding higher voltage values is because when the oscillicope probe is passed through the ferrite core the voltage that is induced inside the core is also taken into account together with the voltage across the resistor. Lastly it was also observed that this was in fact a step down transformer.

8. References

[1] F.T. Ulaby, E. Michielssen and U. Ravaioli, *Fundamentals of Applied Electromagnetics,* 6th Edition, Pearson Education, NJ, 2010.

[2] Odendaal J.W. 2012, *Study Manual, Antennas and Microwaves EMZ320*, University of Pretoria