



THE TRANSFORMER

1. Aim

In this lab session the transformer operation will be studied and it will be checked the effect of the transformer turns ratio on the voltage.

2. Overview

2.1. Faraday's Law.

In the early 1830s, Michael Faraday in England and Joseph Henry in America independently discovered that a changing magnetic field induces a current in a wire.

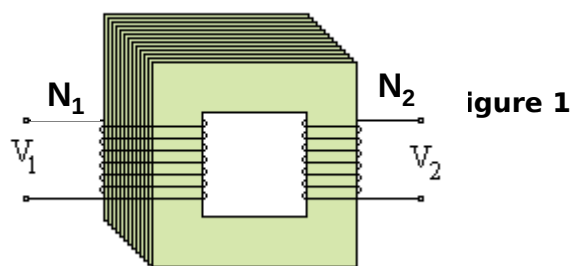
Faraday's law of induction is a basic law of [electromagnetism](#) relating to the operating principles of [transformers](#), [inductors](#), and many types of [electrical motors](#) and [generators](#).

The law states that, "The induced [electromotive force](#) (EMF) in any closed circuit is equal to the time rate of change of the [magnetic flux](#) through the circuit".

$$\varepsilon = -\frac{d\Phi}{dt} \quad [1]$$

2.2. The transformer

A transformer is a device used to raise or lower the voltage in a circuit without an appreciable energy loss. A simple transformer is shown in Figure 1. It consists of two wire coils around a common iron core.



The coil used for the input power is called the primary coil, and the other one is denoted as secondary coil. Either coil of a transformer can be used as the primary or secondary coil. An alternating current in the primary coil creates a varying magnetic field in the transformer's core. This varying magnetic field gives place to a varying magnetic flux through the secondary coil, inducing an alternating **emf** or voltage in the secondary coil. The presence of the iron core increases the magnetic field due to the electric current passing through the first coil and also let all the magnetic field lines pass through both coils.

For an ideal transformer, it is possible to establish a relationship between the alternating voltage induced in the secondary coil, V_2 and the alternate voltage in the primary coil V_1 . They are related by the expression:

$$\frac{V_2}{V_1} = \frac{N_2}{N_1} \Rightarrow V_2 = \frac{N_2}{N_1} V_1 \quad [2]$$

where N_1 , N_2 are the number of turns in the primary and secondary coils, respectively.

If $N_2 > N_1$ then $V_2 > V_1$, so the voltage in the secondary coil is greater than the voltage in the primary coil, (**step-up transformer**). On the contrary, if $N_2 < N_1$ then $V_2 < V_1$, therefore the voltage in the secondary coil is less than the voltage in the primary coil. In this last case the transformer is called a **step-down transformer**. Thus, transformer can be used either for increasing or decreasing an alternating voltage.

The expression given in [2] corresponds to an ideal transformer. In this case all magnetic field lines (and thus, the magnetic flux) are enclosed within the transformer core. However, in a real transformer, part of the field lines escape from the iron core, so that not all the magnetic field lines pass through the secondary coil. Therefore, the magnetic flux and the induced voltage V_2 on the secondary coil will be lower than in the ideal case. If the fraction of the magnetic field lines created by the primary coil that pass through the secondary coil is denoted by f , in this case the relationship given in [2] becomes into the following expression:

$$V_2 = f \frac{N_2}{N_1} V_1 \quad [3]$$

$100f$ represents the percentage of induced voltage in the coil secondary with respect to the ideal case. f is called the **transformer performance**.

3. To learn more...

- P.A. Tipler, G. Mosca, "Physics" (Chapter 31, Section 31.7), 4th edition, Ed. Thomson.
- R.A. Serway, J.W. Jewett, Jr., Vol. 2 (Chapter 23), 3^a edition, Ed. Thomson, Madrid, 2002.

In internet:

http://www.fisicanet.com.ar/fisica/electrodinamica/ap04_transformadores.php

<http://www.engga.uwo.ca/people/adounavis/courses/ece241b/Labs/lab4.pdf>

<http://farside.ph.utexas.edu/teaching/302l/lectures/node90.html>

<http://www.phys.unsw.edu.au/~jw/transformers.html>

<http://www.seas.upenn.edu/~ese206/labs/Transformer/TransformerLab05.pdf>

4. Material.

1. Transformer Iron core.
2. Coils 200, 400, 800, 1600 and 3200 turns.
3. Oscilloscope.
4. Frequency generator.
5. Connection Cables.

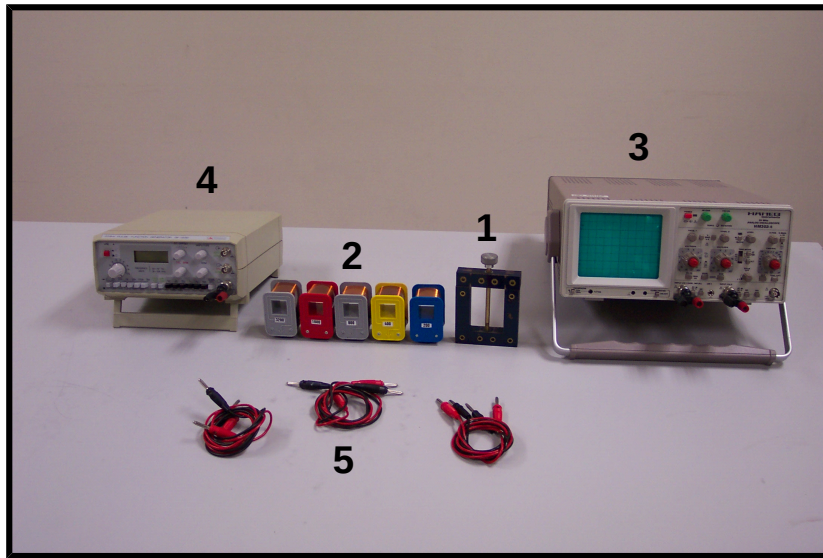


Figure 2

5. Experimental procedure.

The variation of the voltage V_2 in the secondary coil will be studied as a function of N_2 , N_1 and V_1 . The performance of the transformer will be determined in each case.

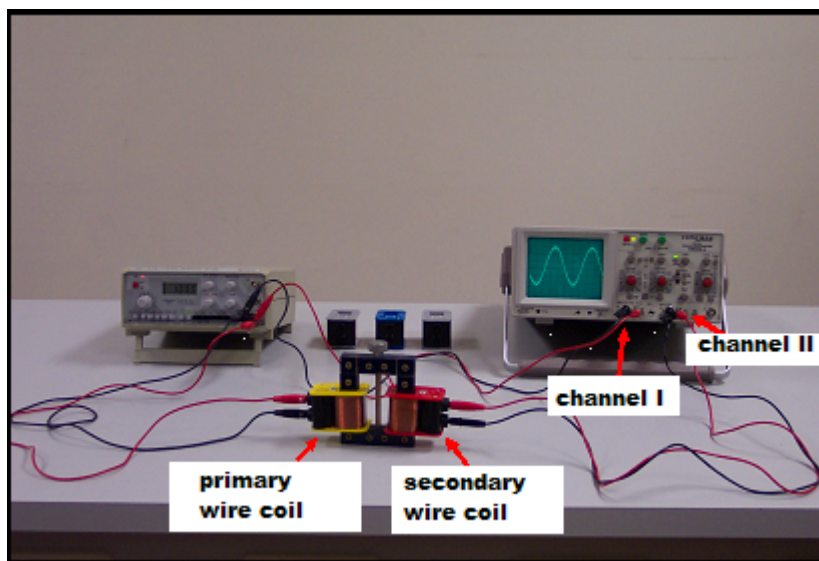


Figure 3

5.1. Study of V_2 in terms of N_2 .

1. Choose the 200 turns coil as primary coil and the 400 turns coil as secondary and place them in the iron core.
2. Connect the 200 turns coil to the frequency generator and to the channel I of the oscilloscope. The secondary coil must be connected to the channel II of the oscilloscope.
3. Turn on the frequency generator and select a sinusoidal output (AC) at a frequency $\nu_0=100$ Hz. Observe the primary coil signal on the oscilloscope (channel I). Determine the peak to peak voltage V_{pp} . The amplitude oscillations V_1 is given by: $V_1 = V_{pp} / 2$.
4. Observe the output voltage in the secondary coil (channel II of the oscilloscope). Measure the period of the oscillations and determine the frequency. The signal must be sinusoidal and with a frequency $\nu_0=100$ Hz, as the input signal. Measure the peak to peak voltage V_{pp} and calculate the signal amplitude. It is given by $V_2=V_{pp}/2$.
5. Repeat the steps indicated above for the coil secondary coils $N_2 = 800, 1600$ and 3200 turns. **IMPORTANT: for all cases keep the same voltage V_1 in the primary coil.**
6. Plot V_2 as a function of N_2 . Fit the data using the least squares formulas.
7. Discuss the meaning of the parameters of the adjustment. For it, use the relationship given in [3] in the overview corresponding to the transformer.
8. Determine the transformer performance from the slope of the straight line. Calculate the uncertainty of the transformer performance.

5.2. Study of V_2 in terms of N_1 .

1. Choose the 200 turns coil as primary coil and the 3200 turns coil as secondary. Use the frequency generator to put a sinusoidal signal of $\nu_0=100$ Hz as input signal in the primary coil. Following the procedure indicated in the section 5.1, find the voltages V_1 and V_2 in the primary and secondary coils, respectively.
2. Repeat the same measurements for a primary coil with $N_1 = 400, 800$ and 1600 turns. **IMPORTANT: for all cases keep the same voltage V_1 in the primary coil.**
3. Plot $\ln(V_2)$ as a function of $\ln(N_1)$. Fit the data using the least squares formulas.
4. Discuss the meaning of the parameters of the adjustment. For it, use the relationship given in [3] in the overview corresponding to the transformer.
5. Determine the transformer performance from the slope of the straight line. Calculate the uncertainty of the transformer performance.

5.3. Study of V_2 in terms of V_1 .

1. Perform the same setup as in the previous sections. Choose the 200 turns coil as the primary coil and the 3200 turns coil as the secondary coil. Put a sinusoidal signal of frequency $\nu_0=100$ Hz as input signal in the primary coil.
2. Measure the voltage V_2 on the secondary coil. By changing the voltage in the primary coil in the range 0.1-1 volt, realize at least 5 measurements.
3. Plot V_2 as a function of V_1 . Fit the data using the least squares formulas.
4. Discuss the meaning of the parameters of the adjustment. For it, use the relationship given in [3] in the overview corresponding to the transformer.
5. Determine the transformer performance from the slope of the straight line. Calculate the uncertainty of the transformer performance.

5.4. Compare the three values obtained for the performance of the transformer. Discuss the results.

IMPORTANT: All plots must be accompanied by a table with the data represented. Include in the tables all units and uncertainties of the measurements.