جامعة محمد بوضياف- المسيلة -
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كلية التكنولوجيا
Faculty of Technology
قسم الهندسة الكهربائية و قسم الإلكترونيك
Department of Electrical Engineering and Department of Electronics
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University year: 2024/2025 — السنة الجامعية: 2024 /2025

2nd year Electrical Engineering and Electronics — السنة الثانية هندسة كهربائية و إلكترونيك

Applied Work in Fundamentals of Electrotechnics 1 — أعمال تطبيقية في الكهروتقني الأساسية 1
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PW n°03 : The hysteresis cycle

Duration : 1^h30.

Date of the experiment: ………. /……../………….. ..

Report prepared by:

Last Name	**First Name**	**Group**	**S/Group**	**Final Note**
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Instructions :

- **Internal laboratory regulations must be observed.**
- **You must wear a lab coat.**
- **Attendance is compulsory and will be monitored. Any unjustified absence or failure to hand in a report will result in a mark of 0/20.**
- **Have your assemblies checked before connecting the voltage source.**
- **It is strictly forbidden to move equipment from one station to another. In the event of a breakdown or faulty equipment, contact the teacher.**
- **The report must be written by a maximum of four students.**
- **The report must be handed in at the beginning of the next session.**
- **The report must include the following sections:**
  - **TP cover page.**
  - **The date of the practical session.**
  - **Last Name and first name of the main writer.**
  - **Last Names and first names of the WP participants.**
  - **Preparation and work in manuscript.**

I- Aim of the manipulation:

- Learn the correct measurement methods using the CASSY Lab interface.
- Learn how to visualise the B(H) hysteresis cycle of a magnetic material and evaluate its hysteresis losses using the CASSY Lab software.

II. Theoretical reminder

II.1 Magnetic circuit definition

A magnetic circuit is the volume in which all the lines of force of a magnetic field converge (Fig-1).
In all areas where magnetic phenomena are used (e.g. machines, transformers, etc.), the lines of force must converge in a circuit that is a good conductor of magnetic flux.
This circuit is made of ferromagnetic materials, especially iron.
A magnetic field can be created using permanent magnets or electric circuits through which current flows.

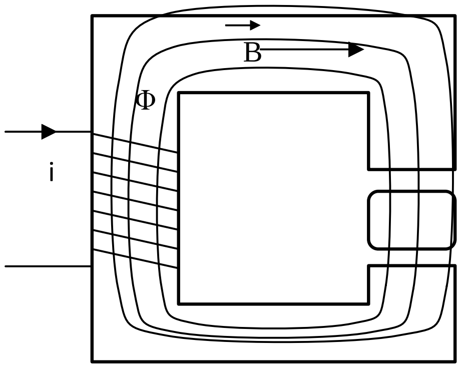

Figure 1

II.2 Magnetic fields and magnetic induction

When a magnetic field **H** circulates in a ferromagnetic material, a magnetic induction **B** is created in the material (Fig-2), the variation of which follows the relationship:

$\vec{B} = \mu \vec{H}$ with $\mu = \mu_r \, \mu_0$ where

$\vec{H}$: Magnetic field or magnetic field strength (A/m)

$\vec{B}$: Magnetic induction (Tesla)

μ : Absolute permeability of a magnetic material

μ_0: Vacuum permeability $\mu_0 = 4\pi 10^{-7}$ H/m

μ_r : Relative permeability of a material.

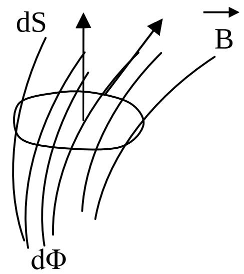

Figure 2

II.3 Magnetic flow

The flux of magnetic $\vec{B}$ induction through a surface **S** is

$\Phi_s = \iint \vec{B}.\vec{ds}$ or else $d\Phi = \vec{B}.\vec{ds}$.

II.4 Relationship between current and magnetic field (Ampère's theorem)

The magnetic field circulating along a closed induction line **Γ** passing **n** times through an electric circuit carrying a current **i** (Fig-3) is related to the current by Ampère's theorem:

$\oint_\Gamma \vec{H}.\vec{dl} = ni$ n : Number of turns of the coil

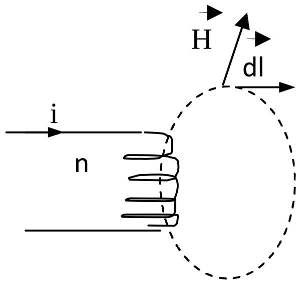

Figure 3

II.5- Relationship between voltage and magnetic flux ratio

When a variable or alternating magnetic flux passes through a winding with n turns (Fig-4), a counter-electromotive force (voltage) is generated between the terminals of this winding:

$e = -n \; d\Phi / dt$

Φ : Magnetic flow passing through the surface of the windings.

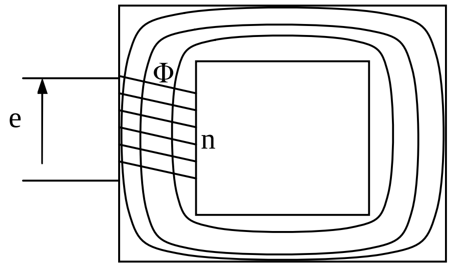

Figure 4

II.6 Magnetisation curve :

The magnetic field and induction are related by the relation :

$$\vec{B} = \mu\ \vec{H} = \mu_r\ \mu_0\ \vec{H}$$

- In *non-magnetic* media and materials (air, copper, aluminium) where $\mu_r = 1$ c to d $\vec{B} = \mu_0\ \vec{H}$, the B (H) characteristic is linear (straight form).(Fig-5)

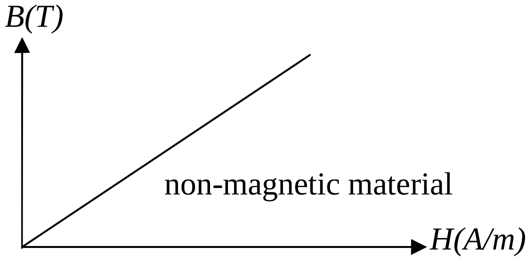

Figure 5

- *Ferromagnetic* materials (such as iron) are characterised by a non-linear magnetisation curve in which the relative permeability μ_r varies with the value of the induction B. (Fig-6)

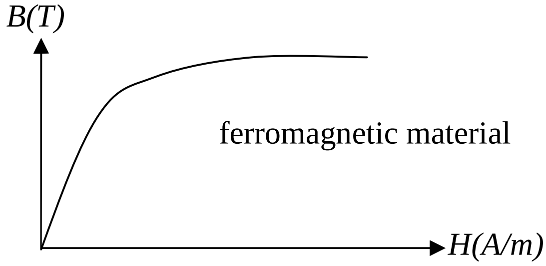

Figure 6

II.7 Hysteresis phenomenon:

When a ferromagnetic material is subjected to an alternating to an alternating magnetic field the B(H) characteristic follows different during magnetisation and demagnetisation.
During each period, the B(H) characteristic describes a closed cycle called the ***hysteresis cycle*** (Fig-7).

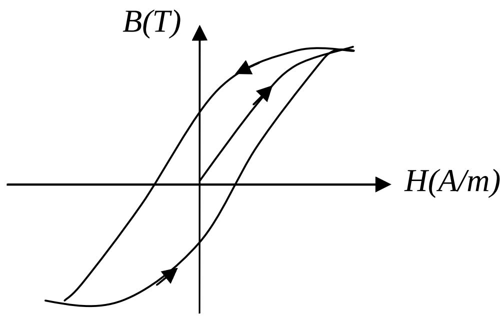

Figure 7

II.8- Magnetic losses:

They represent the active power dissipated in a magnetic circuit through which a variable or alternating magnetic flux flows. These losses are mainly due to the currents induced in the material by the effect of the flux variation (eddy currents) and also to the hysteresis phenomenon.

II.9 Hysteresis losses:

The change in magnetic energy per unit volume in a magnetic substance is given by a magnetic substance is given by : $dW = \vec{H}.\vec{dB}$

The energy dissipated during a period T is: $W = \int_0^T dW = \int_0^T H.dB$

This integral represents the area of the hysteresis cycle described during one period (Fig-8).

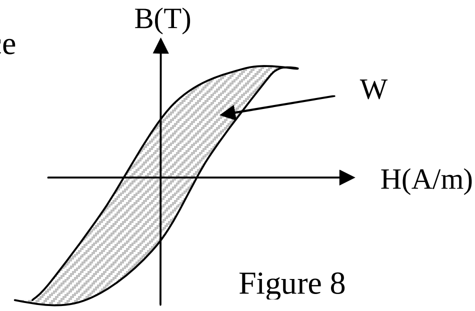

Figure 8

The total magnetic energy dissipated in a substance of volume V during a period is calculated by integrating W over the volume of the substance:

$$W_T = \int_V W\ dv = W.V$$

Finally, the active power dissipated in the material (hysteresis losses) is calculated:

$$P_h = {dW_T}/{dt} = \frac{W_T}{T} = W_T . f$$

II- Magnetic field and induction measurement method

Look at the diagram below:

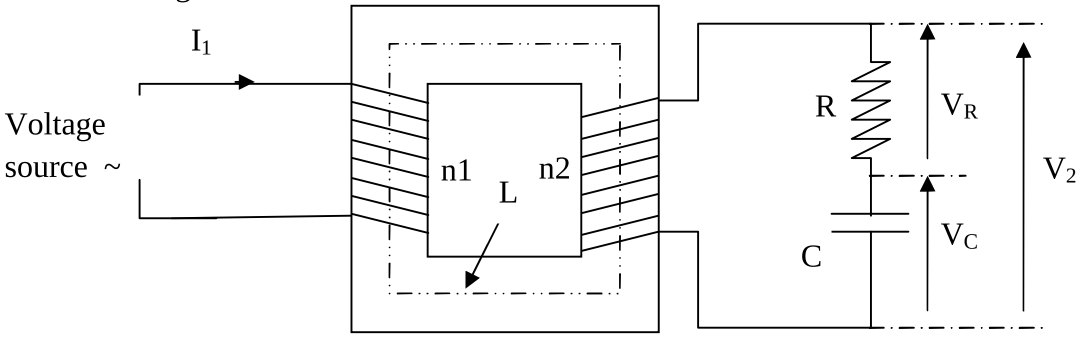

Figure 9

It is a closed magnetic circuit made of ferromagnetic material. This circuit consists of two electrical windings with the number of turns $\mathbf{n_1}$ and $\mathbf{n_2}$. The winding **(1)** is supplied by a **50 Hz** alternating voltage source

- **Primary side:**

Applying Ampère's theorem to this circuit, we can write down the relationship between the magnetic field **H** in the magnetic circuit and the current $\mathbf{I_1}$.

Applying Ampère's theorem to the circuit, we obtain $n_1.I_1 = H.L$ where **L**: is the average length of the magnetic circuit.

hence : $$H = \frac{n_1}{L} I_1$$

- **Secondary side:**

At the terminals of the winding (2) we have: $V_2 = -n_2.\frac{d\Phi}{dt} = V_R + V_c$

Φ is the magnetic flux density **B**. The voltage across capacitor C is: $V_c = \frac{1}{C}\int i_2\, dt$

The choice of **R** and **C** is such that the impedance $1/C\omega$ is negligible compared to **R**.

This allows us to write $V_2 \cong V_R = R.i_2$

Hence :

$$V_c = \frac{1}{RC}\int V_2\, dt = -\frac{n_2}{RC}\int (\frac{d\Phi}{dt})dt = -\frac{n_2}{RC}\Phi$$

Now we have: $\Phi = B.S$ where S is the cross-sectional area of the magnetic circuit. Finally, we have:

$$V_c = -\frac{n_2 S}{RC} B \quad \text{Hence} \quad : \boxed{B = -\frac{RC}{n_2 S} V_C}$$

Conclusion :

We can see that the current $\boldsymbol{I_1}$ and the voltage $\boldsymbol{V_c}$ are respectively the image of the magnetic field ***H*** and the magnetic induction ***B***. Displaying the ***B(H)*** characteristic on **CASSY Lab** is therefore the same as displaying the $\boldsymbol{V_c (I_1)}$ characteristic.

IV. Practical study

IV.1 Manipulation:

1. Carry out the assembly shown in the following figure:

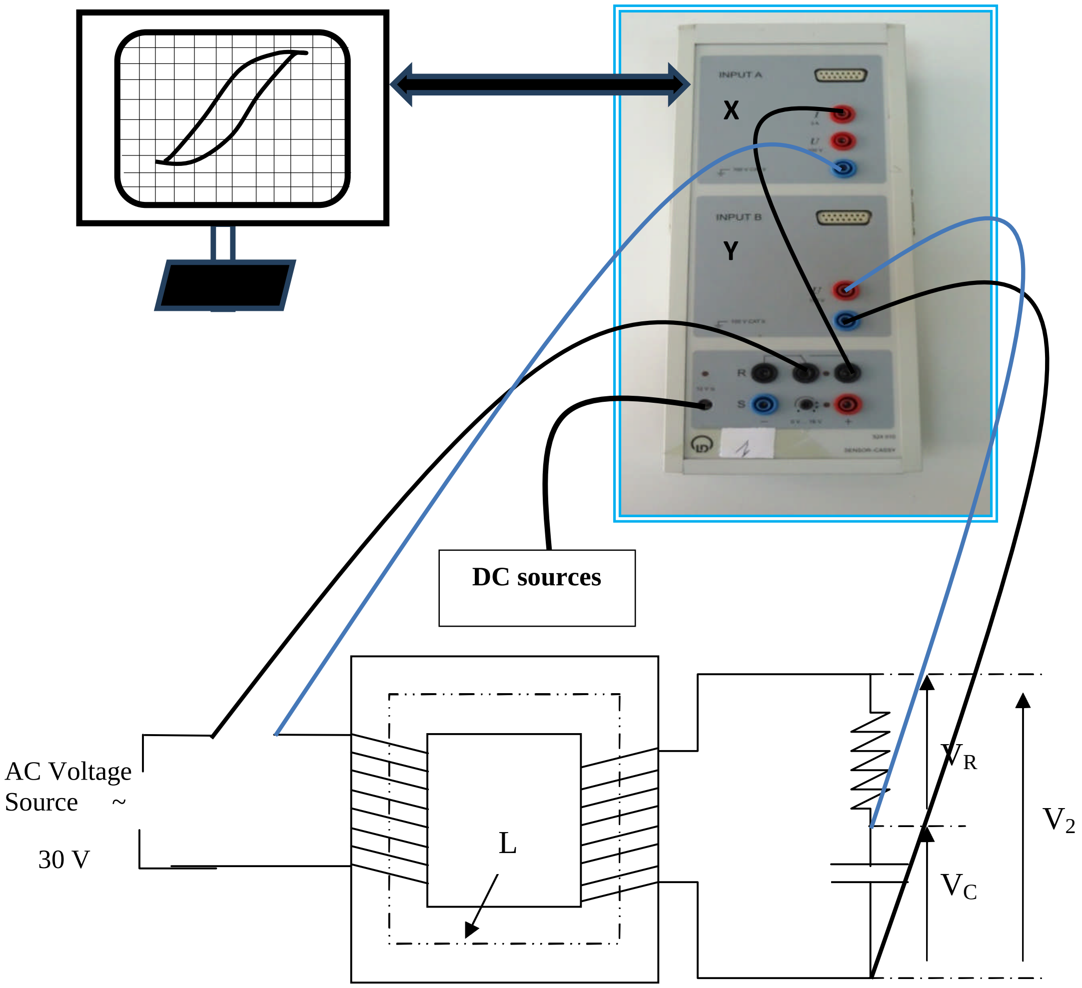

Figure 10

We give:

R= 1 kΩ
C = 16 µF

n_1 = 300, number of primary windings
n_2 = 140 , number of secondary windings
S = 9 cm^2, magnetic circuit cross section
L = 35,2 cm, average length of magnetic circuit

Person in charge of practical work: Dr ROUABHI.R

2. Apply the current I_1 to input **X** of the **CASSY Lable** and the voltage V_C to input ***Y***.
3. Visualise the shape of the voltage V_C on the capacitor ***C***.
4. Complete the following table:

Table 1

T (ms)	0	2	4	6	8	10	12	14	16	18	20
V_C(mV)											
B(T)											

5. Plot the two curves $V_C(t)$, ***B(t)*** on the same graph paper.
6. Visualise the shape of the primary winding current.
7. Complete the following table:

Table 2

t(ms)	0	2	4	6	8	10	12	14	16	18	20
I_1(mA)											
H(A/m)											

8. Draw the two curves $I_1(t)$, ***H(t)*** on the same graph paper.
9. Eliminate the time base on **CASSY Lab** to visualise the $V_C\,(I_1)$ characteristic.
10. From Tables **1** and **2**, plot the ***B(H)*** curve on graph paper.
11. Interpret the hysteresis cycle curve.
12. Measure the area of the hysteresis cycle and deduce the energy dissipated, per period and per unit volume of ferromagnetic material used, for this level of induction.
13. Calculate the hysteresis loss P_h of the circuit used.
14. Draw a conclusion.