الجمهورية الجزائرية الديمقراطية الشعبية
PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA

وزارة التعليم العالي و البحث العلمي
جامعة محمد بوضياف بالمسيلة
كلية التكنولوجيا
قسم الهندسة الكهربائية

MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH
MOHAMED BOUDIAF UNIVERSITY OF M'SILA
FACULTY OF TECHNOLOGY
DEPARTMENT OF ELECTRICAL ENGINEERING

رقم:22/ ق.هـ.ك /2025 المسيلة في : 29 جانفي 2025

# شهادة إدارية

## بخصوص مطبوعة الدروس الخاصة بالأستاذ

## روابحي رياض

بناءً على محضر اللجنة العلمية لقسم الهندسة الكهربائية تحت رقم: 365/ق.هـ.ك/2024 المنعقد بتاريخ 06 نوفمبر 2024 والمتضمن تعين الخبراء: الأستاذ شودار عيسى أستاذ بجامعة المسيلة الأستاذ رحالي هلال أستاذ محاضر –أ- بجامعة المسيلة، والأستاذ محبوب محمد عبد الباسط أستاذ محاضر –أ بجامعة ورقلة وذلك لتقييم مطبوعة الدروس الخاصة بالأستاذ روابحي رياض أستاذ محاضر "أ" بقسم الهندسة الكهربائية لجامعة المسيلة تحت عنوان :

" Électronique et électrotechnique fondamentales 1 "

مطبوعة دروس مكتوبة باللغة الإنجليزية تحت عنوان:

" Fundamental Electronics and Electrotechnics 1 "

وبعد إطلاع رئيس اللجنة العلمية ورئيس القسم على التقارير الواردة و التي كانت كلها ايجابية، وعليه فإن اللجنة لا ترى مانعا أن تتخذه سندا في تدريس طلبة السنة الثانية ليسانس في الكهروتقني والألية والكهروميكانيك والطاقات المتجددة ، شعبة الكهروتقني والألية والكهروميكانيك والطاقات المتجددة على التوالي ، ميدان علوم و تكنولوجيا و أن تعتمد في أي تقييم للمسار العلمي للأستاذ المعني.

رئيس اللجنة العلمية
أ.د بوقرة عبد الرحمان

رئيس القسم
دفداف المبروك

ملاحظة: سلمت هذه الشهادة للمعني(ة) لاستعمالها في حدود ما يسمح به القانون.

**Semestre: 3**
**Unité d'enseignement: UEM2.1**
**Matière 3:TP d'Electronique 1 et d'Electrotechnique 1**
**VHS: 22h30 (TP: 1h30)**
**Crédits: 2**
**Coefficient: 1**

**Objectifs de l'enseignement**

Consolidation des connaissances acquises dans les matières d'électronique et d'électrotechnique fondamentales pour mieux comprendre et assimiler les lois fondamentales de l'électronique et de l'électrotechnique.

**Connaissances préalables recommandées**

Contenu du cours des deux matières "Electronique fondamentale" et "Electrotechnique fondamentale".

**Contenu de la matière :**

L'enseignant de TP est appelé à réaliser au minimum 3 TP d'Electronique et 3 TP d'Electrotechnique parmi la liste des TP proposés ci-dessous :

**TP d'Electronique 1**

T.P.1. Théorèmes fondamentaux
T.P.2.Caractéristiques des filtres passifs
T.P.3. Caractéristiques de la diode / redressement
T.P.4. Alimentation stabilisée avec diode Zener
T.P.5. Caractéristiques d'un transistor et point de fonctionnement
T.P.6. Amplificateurs opérationnels.

**TP d'Electrotechnique 1**

T.P.1 Mesure de tensions et courants en monophasé

T.P.2 Mesure de tensions et courants en triphasé

T.P.3 Mesure de puissances active et réactive en triphasé

T.P.4 Circuits magnétiques (cycle d'hystérésis)

T.P.5 Essais sur les transformateurs

T.P.6 Machines électriques (démonstration).

**Mode d'évaluation :** Contrôle continu: 100 %.

**Références bibliographiques:**

(Selon la disponibilité de la documentation au niveau de l'établissement, Sites internet...etc.)

People's Democratic Republic of Algeria Ministry of Higher Education and Scientific Research

Mohamed Boudiaf University at M'Sila

1985

جامعة محمد بوضياف - المسيلة
Université Mohamed Boudiaf - M'sila

Faculty of Technology

Department of Electrical Engineering

# Practical work handout

Subject: Fundamental Electronics and Electrotechnics 1

Speciality: Electrotechnics, Electromechanics, Automatic, Renewable energy and environment.

Level: 2nd year bachelor's degree

Author: Riyadh ROUABHI

Academic Year: 2024-2025

***Author***

Dr: ROUABHI Riyadh
riyadh.rouabhi@univ-msila.dz

Faculty/Institute: Faculty of Technology
Department: Electrical Engineering
Institution: Mohamed BOUDIAF University of M'sila - Algeria

Subject title: **Fundamental Electronics and Electrotechnics 1**

Semester: 03
Fundamental Teaching Unit Code: UEM2.1
Number of teaching hours of practical work 09.00 h
Number of hours of personal work for the student: 1.5 h
Number of credits: 2; Subject coefficients: 1

## *Foreword*

With a view to applying the new university syllabuses proposed by the national educational councils as part of the overhaul of the curricula initiated by the Ministry of Higher Education and Scientific Research, this book has been written mainly as a teaching tool with the aim of facilitating and providing students in the 2nd year of a degree in Electrical Engineering, Electromechanics, Automation, Renewable energy and environment with the basic principles of electronics and electrotechnics.

## *PW n°01: Measuring Voltage, Current and Power in Single Phase (Electrotechnics)*

***Aim***

- ✓ To learn about the different electrical elements (electrical charges, electrical sources, measuring instruments, etc.).
- ✓ To learn the correct way of measuring with all the measuring instruments (amperemeter, voltmeter, power meter, etc.).
- ✓ To give general help on the influence of electric charges on the power measured in alternating current circuit

***Equipment used***

- ➢ Voltage sources (AC).
- ➢ Electrical loads (resistors, inductors and capacitors).
- ➢ Measuring instruments (voltmeters, ammeters, multimeters, power meters)

## *PW n°02: Measuring Voltage, Current and Power in Three Phases (Electrotechnics)*

***Aim***

- ✓ To learn how to measure three-phase voltage, current, active power and reactive power.
- ✓ To learn the three methods of measuring three-phase power: the one wattmeter method, the two wattmeter method and the three wattmeter method.
- ✓ Depending on the configuration (star or delta) and the type of three-phase receiver (balanced or unbalanced), you can choose the appropriate method for measuring electrical power.

***Equipment used***

- ➢ Three-phase (AC) power sources.
- ➢ Three-phase electrical loads (resistors, coils and capacitors).
- ➢ Measuring instruments (multimeters, wattmeters, power meters).

## *PW n°03: The hysteresis cycle (Electrotechnics)*

***Aim***

- ✓ To learn the correct methods of measurement using the CASSY Lab interface
- ✓ To learn how to visualise the B(H) hysteresis cycle of a magnetic material and to evaluate the hysteresis losses of this material using the CASSY Lab software

***Equipment used***

- ➢ Voltage sources (AC).
- ➢ Single-phase transformer.
- ➢ Electrical loads (resistors and capacitors).
- ➢ Measurement equipment (computer, CASSY Lab interface, etc.).

## *PW n°04: Tests on single phase transformer (Electrotechnics)*

***Aim***

- ✓ To present a general method for determining the parameters of the equivalent diagram of a single-phase transformer.

***Equipment used***

- ➢ Single-phase voltage sources (AC/DC).
- ➢ Electrical loads (rheostats).
- ➢ Measuring instruments (voltmeters, ammeters, multimeters, power meters)
- ➢ .Single-phase transformers.

## *PW n°05: Direct current machines (Electrotechnics)*

***Aim***

- ✓ General study of a DC machine for the two modes of operation: generator and motor.

***Equipment used***

- ➢ DC voltage sources.
- ➢ Rheostats.
- ➢ Measuring instruments (voltmeters, ammeters, multimeters).
- ➢ Separately excited generators.
- ➢ Separately excited motors.

## *PW n°01: Introduction to equipment and essential reminders (Electronics)*

***Aim***

- ✓ The primary objective of this laboratory exercise is to familiarize students with electrical components, including resistors, measuring instruments, and the wiring of direct current (DC) electrical circuits.
- ✓ We will specifically examine the laws relating charge and potential difference for resistors, as well as practical applications of these laws in measuring electric current.

***Equipment used***

- ➢ Digital DC Power Supply with Analog and Digital Display
- ➢ Analog Voltmeter
- ➢ Analog Ammeter
- ➢ Digital Multimeter
- ➢ Oscilloscope
- ➢ Function Generator (Low-Frequency Generator, GBF)
- ➢ Test Bench
- ➢ Cables and Probes

## *PW n°02: Superposition Theorem (Electronics)*

***Aim***

- ✓ This experiment aims to analyze circuits containing multiple voltage or current sources by isolating the effect of each source individually. This method simplifies the problem-solving process, providing a clear understanding of how each source influences the overall circuit behavior.

***Equipment used***

- Digital DC power supply with analogue and digital display
- Analogue voltmeter
- Analogue ammeter
- Digital multimeter
- Test bench
- Cables

## *PW n°03: Thevenin's Theorem (Electronics)*

***Aim***

- ✓ The purpose of this lab session is to model complex electrical circuits and simplify them into very basic circuits, allowing us to apply the fundamental laws of electricity without any complex calculations.

***Equipment used***

- Digital DC power supply with analogue and digital display
- Analogue voltmeter
- Analogue ammeter
- Digital multimeter
- Test bench
- Cables

## *PW n°04: PN junction diode characteristics (Electronics)*

***Aim***

- ✓ The main objective of this practical work is to study the influence of forward and reverse bias on the current of a PN junction diode and also to plot the current-voltage characteristic of a PN junction diode. current of a PN junction diode and also to plot the current-voltage characteristic of a diode in the forward and reverse directions.

***Equipment used***

- Digital DC power supply with analogue and digital display
- Diode 1N4007
- Analogue voltmeter
- Analogue ammeter
- Digital multimeter
- Test bench
- Cables

## PW n°01: Measuring Voltage, Current and Power in Single Phase (Electrotechnics)



## PW n°02: Measuring Voltage, Current and Power in Three Phases (Electrotechnics)

## PW n°03: The hysteresis cycle (Electrotechnics)



## PW n°04: The single phase transformer (Electrotechnics)

## PW n°05: Direct current machines (Electrotechnics)



## PW n°01: Introduction to equipment and essential reminders (Electronics)

## PW n°02: Superposition Theorem (Electronics)



## PW n°03: Thevenin's Theorem (Electronics)



## PW n°04: PN junction diode characteristics (Electronics)

# *PW n°01 : Measuring Voltage, Current and Power in Single Phase*

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.**
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- **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.**

Person in charge of practical work: Dr ROUABHI.R

## I- Aim of the manipulation:

The aim of this experiment is to learn how to measure voltage, current, active and reactive power and power factor in a single-phase circuit.

## II- Equipment used:

- Power sources (AC).
- Electrical loads (resistors, inductors and capacitors).
- Instruments (multimeters, power meters).

## III- Evaluation method:

Continuous assessment: 100%.

## IV- Theoretical reminder:

**Note :**

**i, u:** instantaneous values of current and voltage respectively.

**I, U:** effective values of current and voltage respectively.

### 1) The electrical voltage:

It is a difference in potential (d.p) between two points, reflecting an electrical imbalance or different electrical charges, and is measured by a voltmeter.

The voltmeter is a device that is connected in parallel with the component or dipole whose terminal voltage is to be measured. There are three types of voltmeters:

1) The analogue voltmeter.
2) The digital voltmeter.
3) The multimeter.

Figure (1) shows the position of the voltmeter in a single phase circuit.

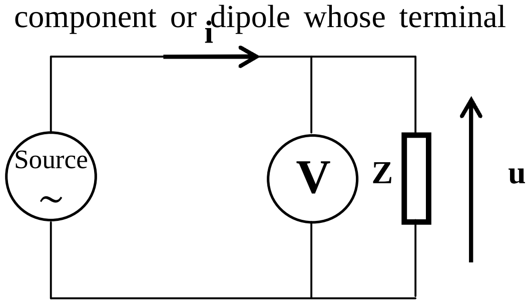


Figure 1

### 2) The electric current:

Electric current results from the movement of electric charges between two points on a branch. Its intensity reflects the flow of moving charges and is measured by an ammeter.

An ammeter is a device connected in series with the component(s) through which the current to be measured flows. There are three types of ammeter:

1) The analogue ammeter.
2) The digital ammeter.
3) The multimeter.

Figure (2) shows the position of the ammeter in a single-phase circuit.

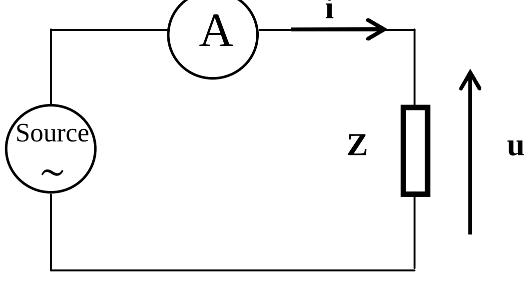


Figure 2

## 3) The electrical power :

Figure (3) shows the position of the power meter in a single-phase circuit.

Any electrical system that uses alternating current contains two forms of power: active and reactive.

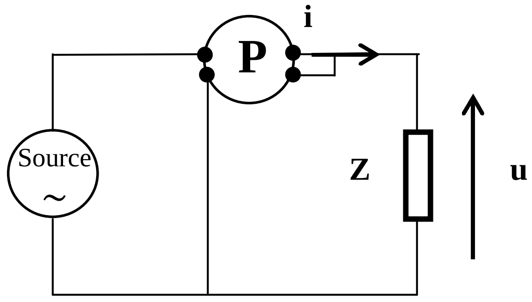


Figure 3

- **The active power P**

It is completely converted into useful energy in the form of mechanical, thermal or light energy. The average active power is defined by the following relationship: $\boxed{P = UI\cos(\varphi)}$ (W)

Where φ is the phase difference between current I and voltage U.

- **The reactive power Q**

It is used to magnetise the magnetic circuits of electrical machines (transformers and motors). The average reactive power is defined by: $\boxed{Q = U\ I\ \sin(\varphi)}$ (VAR)

- **The apparent power S**

It is equal to the vectorial sum of the two active and reactive powers. Apparent power is given by :: $\boxed{S = U\ I}$ (VA)

From the above expressions we can write: $S = \sqrt{P^2 + Q^2}$, and $\cos(\varphi) = \frac{P}{S}$ (power factor)

and $Q = P.\mathrm{tg}(\varphi)$

## 4) Single-phase power measurement

Active power, reactive power and apparent power are measured directly by a power meter. The single-phase power meter is a device for measuring single-phase power. It consists of two coils: a current coil, which measures the current flowing through the load (equivalent to an ammeter), and a voltage coil, which measures the voltage across the load (equivalent to a voltmeter). (fig.3)

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# V- Experiment

## 1) Single phase voltage, current and power measurement:

Carry out the assembly shown in Figure 4:

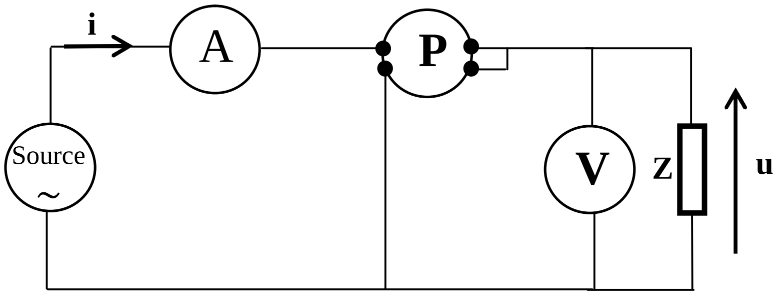


Figure 4

## *PW n°01* : Measuring Voltage, Current and Power in Single Phase

Load Z consists of the series connection of passive elements whose corresponding values are as follows:

- Resistance R=100 Ω; maximum current 1A.
- Iron core coil with inductance L = 60m H and internal resistance r = 1.2 Ω; maximum current 2.5A.
- Capacitor C= 16μF.

**For each receiver**

1. Calculate the value of Z.
2. Complete the following tables (assembly fig.4).

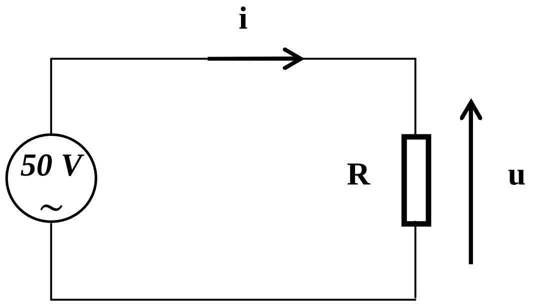

Figure 5

### 1. Load R

U=50V.
R= 100 Ω.

$Z =$ ……………………………………………………

| Greatness | U(V) | I(A) | P(Watt) | Q(Var) | S(VA) | Cos($\varphi$) |
|---|---|---|---|---|---|---|
| Formula | | | | | | |
| Calculation | | | | | | |
| Measurement | | | | | | |

Table 1

What can we conclude?

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### 2. Load L

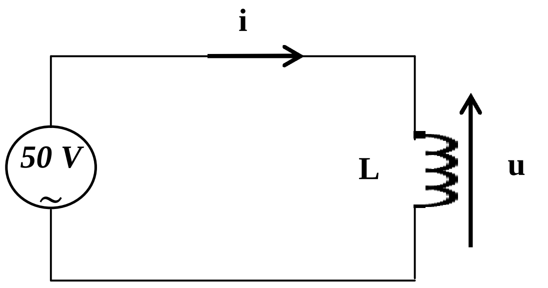

Figure 6

U=50V.
L= 60mH.
r =1.2Ω.
f=50Hz.

$Z =$ ……………………………………………………

| Greatness | U(V) | I(A) | P(Watt) | Q(Var) | S(VA) | Cos($\varphi$) |
|---|---|---|---|---|---|---|
| Formula | | | | | | |
| Calculation | | | | | | |
| Measurement | | | | | | |

Table 2

What can we conclude?

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### 3. Load C

U=50V.
C= 16µF.
f=50Hz.

$Z =$ …………………………………………………

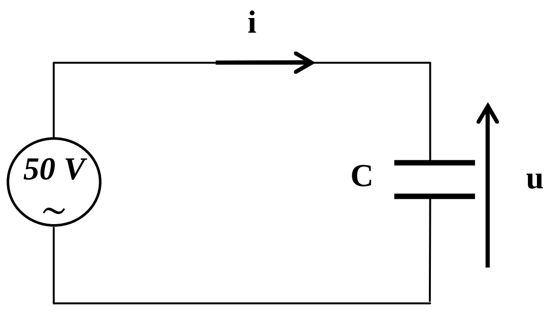


Figure 7

| Greatness | U(V) | I(A) | P(Watt) | Q(Var) | S(VA) | Cos($\varphi$) |
|---|---|---|---|---|---|---|
| Formula | | | | | | |
| Calculation | | | | | | |
| Measurement | | | | | | |

Table 3

What can we conclude?

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### 4. Load RL

U=50V.   R=100Ω.
L= 60mH.
r =1.2Ω.
f=50Hz.

$Z =$ …………………………………………………

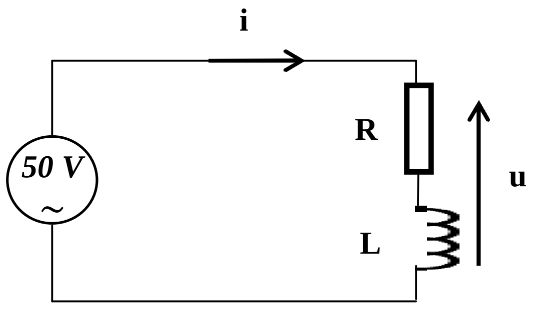


Figure 8

| Greatness | U(V) | I(A) | P(Watt) | Q(Var) | S(VA) | Cos($\varphi$) |
|---|---|---|---|---|---|---|
| Formula | | | | | | |
| Calculation | | | | | | |
| Measurement | | | | | | |

Table 4

What can we conclude?

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**5. Load RLC**

U=50V.

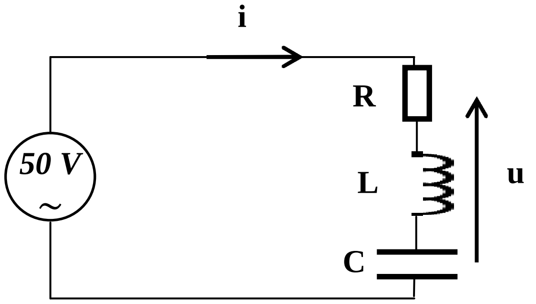
R=100Ω.

L= 60mH.

r =1.2Ω.

C= 16 µF.

f=50Hz.




$Z =$ ………………………………………………………

Figure 9

| Greatness | U(V) | I(A) | P(Watt) | Q(Var) | S(VA) | Cos($\varphi$) |
|---|---|---|---|---|---|---|
| Formula | | | | | | |
| Calculation | | | | | | |
| Measurement | | | | | | |

Table 5

What can we conclude?

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## VI- Conclusion.

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Mohamed Boudiaf University at M'sila
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*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°02 : Measuring Voltage, Current and Power in Three Phases*

Duration : $1^h30$.

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

Report prepared by:

| **Last Name** | **First Name** | **Group** | **S/Group** | **Final Note** |
|---|---|---|---|---|
| - | - | - | - | - |
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## Instructions :

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- **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.**

Person in charge of practical work: Dr ROUABHI.R

## I- Aim of the manipulation:

The aim of this experiment is to measure the voltage, current and active and reactive power in a three-phase circuit.

## II- Equipment used :

- Three-phase voltage sources (AC).
- Electrical loads (resistors, inductors and capacitors).
- Instruments (multimeters, power meters).

## III- Evaluation method:

Continuous assessment: 100%.

## IV- Theoretical reminder :

**Note:** **i, u:** instantaneous values.
**U:** the effective composite voltage between two phases.
**V:** the effective simple voltage between phase and neutral.

## V- Three-phase electrical power

### 01) The active power

The active power, P, is the average value of the instantaneous power. It is equal to the arithmetic sum of the active powers of the three single-phase receivers. In other words, three times the single-phase active power when the system is balanced.

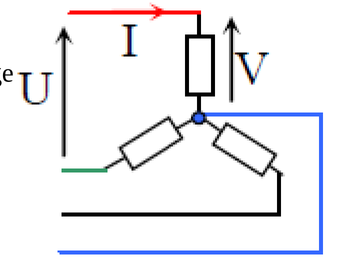
$$P_{\text{three-phase}} = P_1 + P_2 + P_3 = 3 * P_{\text{single-phase}}$$

- Case of a balanced star-coupled system

$$P = 3.V.I.Cos\varphi$$

With $V = U/\sqrt{3}$

$V$ : is the effective value of the phase-to-neutral voltage
$I$ : is the effective value of the line current.
$\varphi$ : is the phase shift of $I$ relative to $V$.

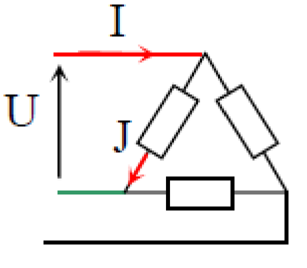



- Case of a balanced delta-coupled system

$$P = 3.U.J.Cos\varphi$$

With $J = I/\sqrt{3}$

$U$ : is the effective value of the phase-to-phase voltage
$J$ : is the effective value of the current of a receiver
$\varphi$: is the phase shift of $J$ relative to $U$




Whatever the coupling for a balanced three-phase system

The active power is given by: $P = \sqrt{3}.U.I.Cos\varphi$



Person in charge of practical work: Dr ROUABHI.R

### 02) The reactive power

The reactive power noted $Q$ is the power brought into play in the reactive dipoles. It is due to the reactance and is expressed in $Var$ (Volt Ampere reactive). It is equal to the arithmetic sum of the reactive powers of the three single-phase receivers. That is to say three times the single-phase reactive power when the system is balanced.

$$Q_{\text{three-phase}} = Q_1 + Q_2 + Q_3 = 3 * Q_{\text{single-phase}}$$

Whatever the coupling for a balanced three-phase system
The reactive power is given by: $Q = \sqrt{3}.U.I.Sin\varphi$

### 03) The apparent power

The apparent power noted S is the power that characterises the generator of the voltage and alternating current sources. When a source of alternating current is made available, we do not know how it will be used by the user and therefore we do not know the phase difference between the current and the voltage. However, it is necessary to know the voltage and current available.
This is equal to the vectorial sum of the apparent powers of the three single-phase sources. In other words, three times the apparent single-phase power when the system is balanced.

$$S_{\text{three-phase}} = S_1 + S_2 + S_3 = 3 * S_{\text{single-phase}}$$

Whatever the coupling for a balanced three-phase system, the apparent power is given by:

$S = \sqrt{3}.U.I$ Or by: $S = \sqrt{P^2 + Q^2}$

The three-phase power factor is: $Cos\varphi = P/S$

## VI- Three-phase power measurement methods

### 01) Single wattmeter method :

This method is valid when the three-phase system is balanced and the neutral is connected (balanced 4-wire system).

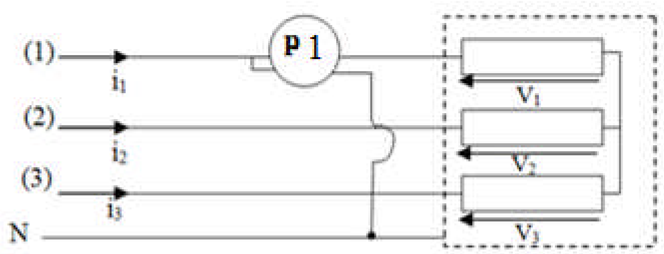



Figure 1

- The current coil is connected to line (1), so the current $I_1$ flows through it. The voltage coil of the same power meter is connected between the lines (1) and the neutral, so it measures the simple voltage $V_1$. The indication on the power meter is therefore :

$P_1 = V_1.I_1.Cos\varphi_1$ and $Q_1 = V_1.I_1.Sin\varphi_1$

We can therefore deduce that the active power of this system is: $P = 3.V_1.I_1.Cos\varphi_1 = 3.P_1$

The reactive power is: $Q = 3.V_1.I_1.Sin\varphi_1 = 3.Q_1$

The apparent power is: $\boldsymbol{S = 3.V_1.I_1 = \sqrt{P^2 + Q^2}}$

### 02) Two wattmeter method:

This measurement method is used for three-phase systems without neutral. It allows the measurement of active and reactive powers. The assembly corresponding to the method is as follows:

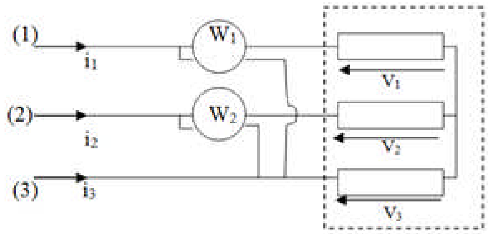


Figure 2

- The current coil of the first wattmeter is connected to line (1), so the current $I_1$ flows through it. The voltage coil of the same wattmeter is connected between lines (1) and (3), so it measures the composite voltage $U_{13}=V_1-V_3$. The indication on the 1st wattmeter is therefore :

$$W_1 = (U_{13}\, I_1)_{moy} = U\,I\cos(\varphi - \frac{\pi}{6}) = U\,I\,(\frac{\sqrt{3}}{2}\cos\varphi + \frac{1}{2}\sin\varphi):$$

- The current coil of the second wattmeter is connected to line (2), so that current I2 flows through it. The voltage coil of the same wattmeter is connected between lines (2) and (3), so it measures the voltage U23=V2-V3, so the indication of the second wattmeter is therefore :

$$W_2 = (U_{23}\, I_2)_{moy} = U I\cos(\varphi + \frac{\pi}{6}) = U I(\frac{\sqrt{3}}{2}\cos\varphi - \frac{1}{2}\sin\varphi)$$

We show that the active power of this three-phase system is the sum of the readings of the two wattmetes:

$$\boxed{P = (W_1 + W_2)}$$

The same applies to reactive power: $W_1 - W_2 = UI\sin\varphi = Q/\sqrt{3}$, therefore : $\boxed{Q = \sqrt{3}(W_1 - W_2)}$

The apparent power is: $\boxed{S = \sqrt{P^2 + Q^2}}$

### 03) Three wattmeter method:

If the three-phase system is unbalanced and with the neutral connected (unbalanced 4-wire system), three power meters must be used to measure the total power.

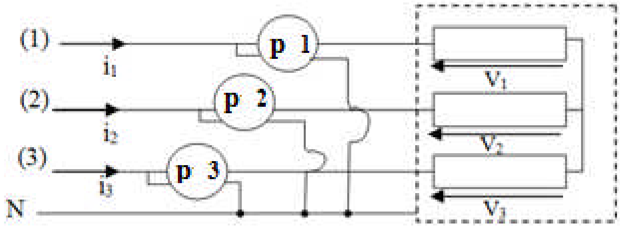


Figure 3

In this case, the active power is: $\boxed{P = P_1 + P_2 + P_3}$

The reactive power is: $\boxed{Q = Q_1 + Q_2 + Q_3}$

The apparent power is: $\boxed{S = \sqrt{P^2 + Q^2}}$

# VII- Practical part:

## 1. Single wattmeter method :

**Purely resistive load:** The three-phase system is balanced and with neutral connected (4-wire balanced system).

1) Carry out the assembly shown in Figure 4:

$U=U_{12}=U_{23}=U_{31}= 50V$

R= ……..Ω
$V_1$= …………………………………..V

Z= ……………………………………
………………………………………..Ω

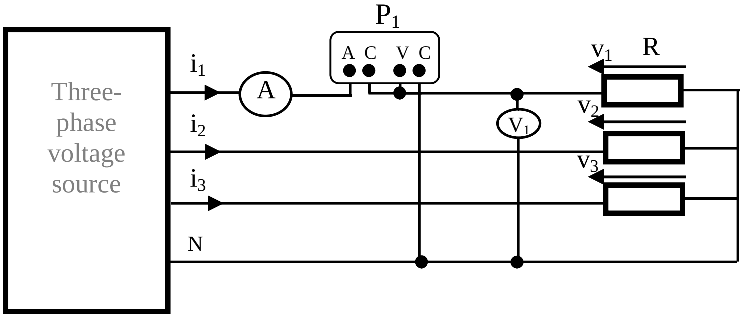



Figure 4

2) Complete the table below:

| Greatness | $V_1$(V) | $I_1$(A) | $P_1$(Watt) | $Q_1$(Var) | $S_1$(VA) | $\cos(\varphi_1)$ |
|---|---|---|---|---|---|---|
| Formula | | | | | | |
| Calculation | | | | | | |
| Measurement | | | | | | |

Table 1

3) Calculate the total power and the power factor.

| Calculations | Measurement |
|---|---|
| $P_{T\_C}$=………………………………………………… | $P_{T\_M}$ =……………………………………… |
| $Q_{T\_C}$=………………………………………………… | $Q_{T\_M}$ =……………………………………… |
| $S_{T\_C}$ = ………………………………………………… | $S_{T\_M}$ = ……………………………………… |
| $\cos(\varphi)$ =…………………………………………… | $\cos(\varphi)$ =………………………………… |

4) What can we conclude ?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

## 2. Three wattmeter method:

**Purely capacitive load**: The three-phase system is unbalanced with the neutral connected (4-wire system) and the load is connected in star configuration.

1) Carry out the assembly shown in 5:

$U_{12}$=$U_{23}$=$U_{31}$=U=50 V
f= 50 Hz.
$C_1$= …………µF.
$C_2$= …………µF.
$C_3$= …………µF.

Z= …………………………
…………………………..…..Ω

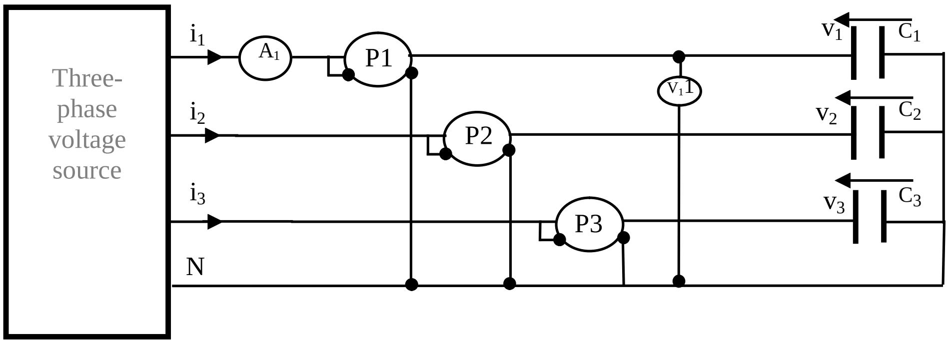



Figure 5

2) Complete the table below: Tab2 et Tab3

| Greatness | $V_1$(V) | $I_1$(A) | $P_1$(Watt) | $Q_1$(Var) | $S_1$(VA) | Cos($\varphi_1$) |
|---|---|---|---|---|---|---|
| Formula | | | | | | |
| Calculation | | | | | | |
| Measurement | | | | | | |

Table 2

| Greatness | $P_2$(Watt) | $Q_2$(Var) | $S_2$(VA) | $P_3$(Watt) | $Q_3$(Var) | $S_3$(VA) |
|---|---|---|---|---|---|---|
| Measurement | | | | | | |

Table 3

3) Calculate the total power and the power factor.

$P_T$=……………………………………………………………………………………………………
$Q_T$=……………………………………………………………………………………………………
$S_T$= ……………………………………………………………………………………………………
Cos($\varphi$) =……………………………………………………………………………………………………

4) What can we conclude?

……………………………………………………………………………………………………………
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……………………………………………………………………………………………………………
……………………………………………………………………………………………………………

## 3. Two wattmeter method :

**Inductive load:** The three-phase system is balanced and has no neutral (balanced 3-wire system).

U= 50 V.
f= 50 Hz.
R= ……......Ω.
L= ………..H.
r= ………..Ω.
Z= ……………………..…
……………….………..Ω

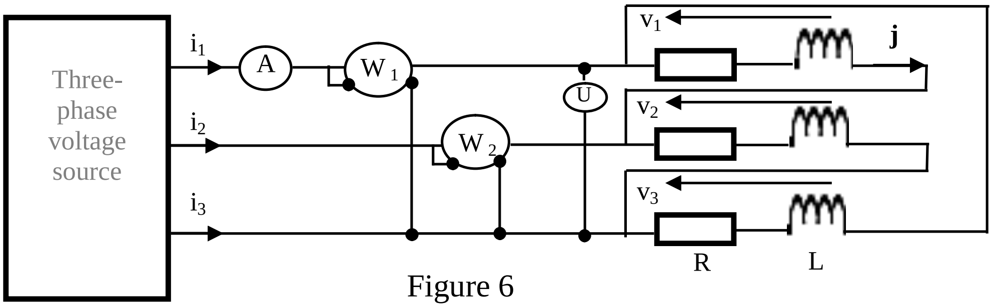


Figure 6

1) Complete the following tables: Table 4 et Table 5

| Greatness | J (A) | $P_{ph1}$(Watt) | $Q_{ph1}$(VAR) | $P_T$(Watt) | $Q_T$ (VAR) | $S_T$ (VA) | Cos($\varphi$) |
|---|---|---|---|---|---|---|---|
| Formula | | | | | | | |
| Calculation | | | | | | | |

Table 4

| Values to be measured | | | | Values to be calculated | | | |
|---|---|---|---|---|---|---|---|
| U(V) | I(A) | $W_1$ | $W_2$ | $P_T$(Watt) | $Q_T$(VAR) | $S_T$(VA) | Cos($\varphi$) |
| . | . | . | . | . | . | . | . |

Table 5

2) What can we conclude?

……………………………………………………………………………………………………………
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## VIII- Conclusion.

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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*

**************************************************************************************************************************

# *PW n°03 : The hysteresis cycle*

Duration : 1$^h$30.

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

Report prepared by:

| **Last Name** | **First Name** | **Group** | **S/Group** | **Final Note** |
|---|---|---|---|---|
| - | - | - | - | - |
| - | - | - | - | - |
| - | - | - | - | - |
| - | - | - | - | - |

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- **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

## 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.

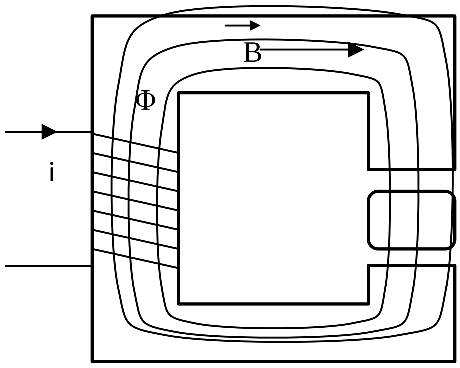

Figure 1

## 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

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

$\mu_r$ : Relative permeability of a material.

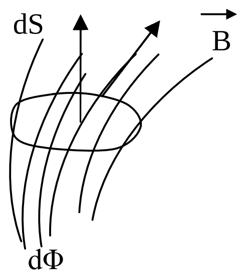

Figure 2

## 3 Magnetic flow

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

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

## 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

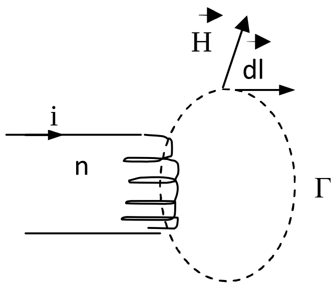

Figure 3

## 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.

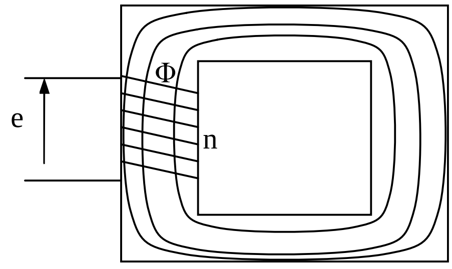

Figure 4



Person in charge of practical work: Dr ROUABHI.R

**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)

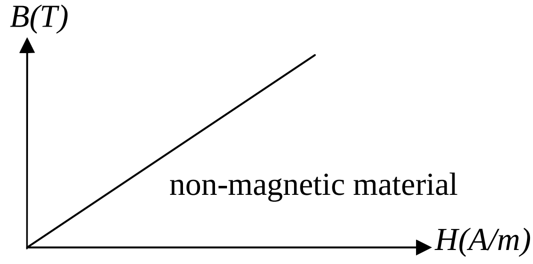


Figure 5

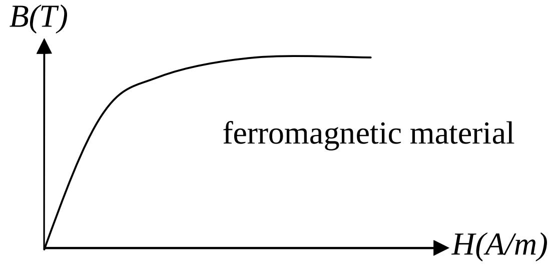


Figure 6

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

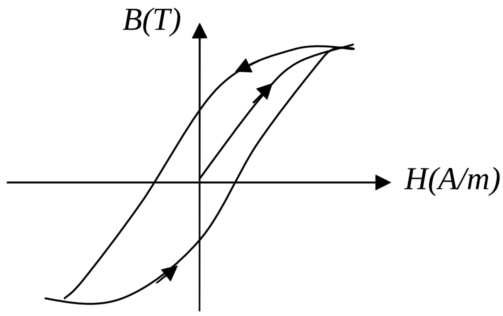


Figure 7

**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 : $dW = \vec{H}\,.d\vec{B}$

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).

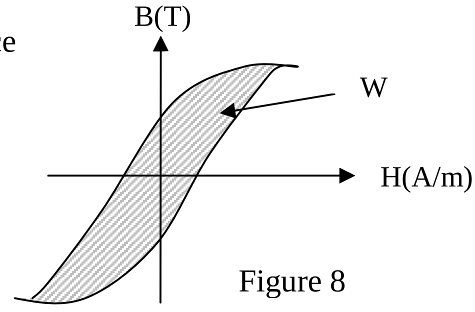


Figure 8

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:

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

## III- Magnetic field and induction measurement method

Look at the diagram below:

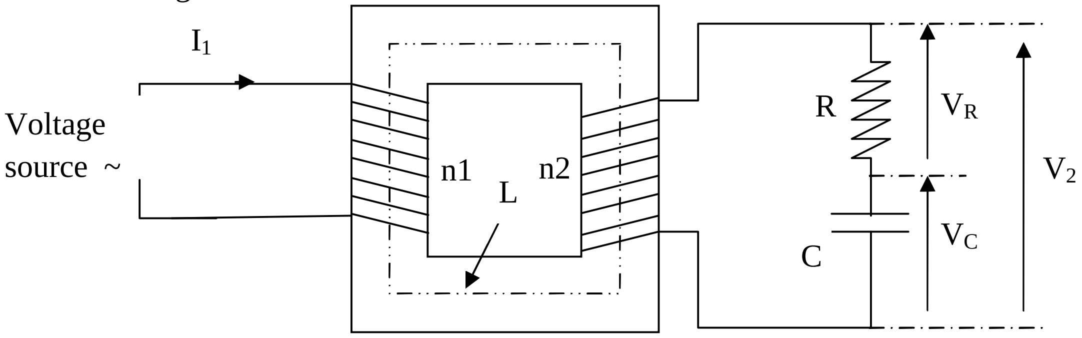


Figure 9

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

### 1 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 : $$H = \frac{n_1}{L} I_1$$

### 2 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 part

## 1 Manipulation:

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

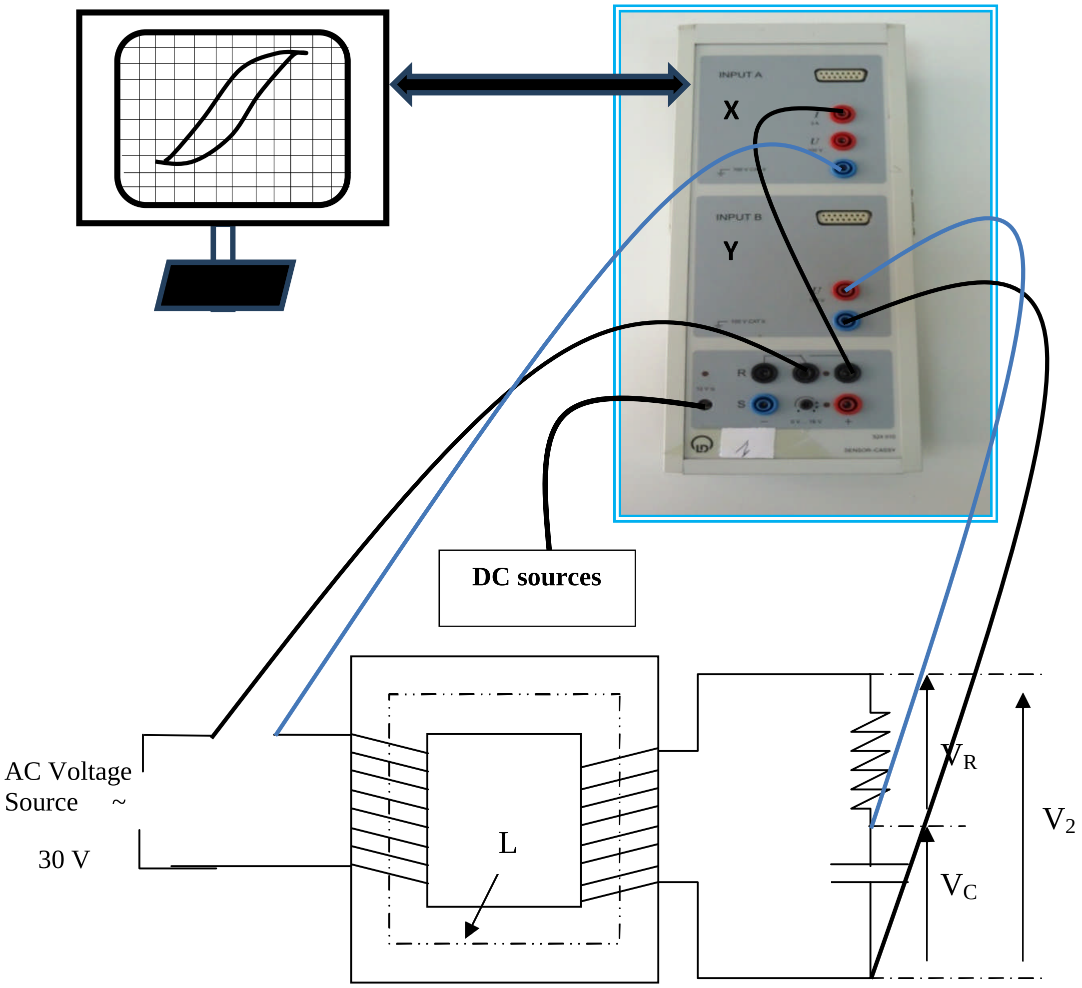


Figure 10

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

# V Work required

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:

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

Table 1

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:

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

Table 2

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.

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*Department of Electrical Engineering and Department of Electronics*
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*University year: 2024/2025* — السنة الجامعية: 2024 /2025
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*Applied Work in Fundamentals of Electrotechnics 1* — أعمال تطبيقية في الكهروتقني الأساسية 1

********************************************************************************************************************

# *PW n°04 : Tests on single phase transformer*

Duration : $1^h30$.

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

Report prepared by:

| **Last Name** | **First Name** | **Group** | **S/Group** | **Final Note** |
|---|---|---|---|---|
| - | - | - | - | - |
| - | - | - | - | - |
| - | - | - | - | - |
| - | - | - | - | - |

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  - **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**

Person in charge of practical work: Dr ROUABHI.R

## I- Aim of the experiment:

The aim of this experiment is to present a general method for determining the parameters of the equivalent diagram of a single-phase transformer.

## II- Equipment used:

- Single-phase voltage sources (AC/DC).
- Electrical loads (rheostats).
- Measuring instruments (voltmeters, ammeters, multimeters, power meters).
- Single-phase transformers.

## III- Theoretical reminder:

### 1) General information

The transformer is a reversible static converter of electrical energy. It transfers, in alternating current, electrical power from a source to a load, by adapting the voltage (or current) values to the receiver.

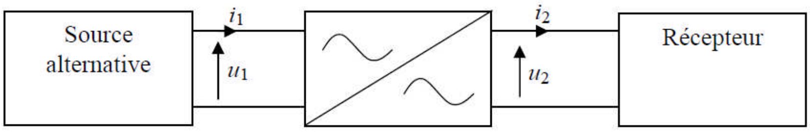


Figure1-Real single-phase transformer

In general, the function of a transformer is to change the RMS value of a voltage without changing its shape (sinusoidal) or frequency. U1 and U2 are the effective values of the voltages U1 and U2 respectively. If U2 >U1: the transformer is a step-up transformer, and if U2 <U1: the transformer is a step-down transformer.

### 2) Real single-phase transformer

The transformer consists essentially of:

-**A magnetic circuit:** Its function is to channel the magnetic flux.

-**Windings:** On the cores of the magnetic circuit there are several windings (electrically isolated from each other), one of which is connected to the source of alternating current: this is the primary winding, which adopts the receiving convention. The other winding (or the others) is the seat of an induced e.m.f. It can flow into a receiver: this is the secondary winding, and the generator convention is adopted.

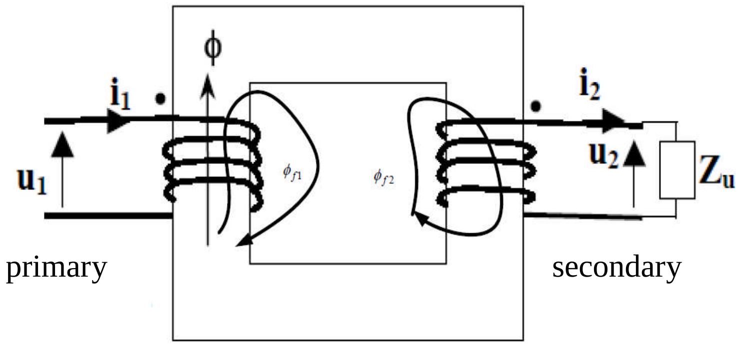


Figure 2–Operating principle of a single-phase transformer.



Person in charge of practical work: Dr ROUABHI.R

## 3) Equivalent diagram

If we designate respectively by:

**$r_1$(Ω)**: resistance of the primary winding, **$r_2$(Ω)**: resistance of the secondary winding.

**$l_1$(H)**: Primary winding inductance, **$l_2$(H)**: Secondary winding inductance.

**Rf(Ω)**: Magnetic circuit resistance. **Xm (Ω)**: Magnetic circuit reactance.

The equivalent diagram of the real transformer is shown in Figure 3.

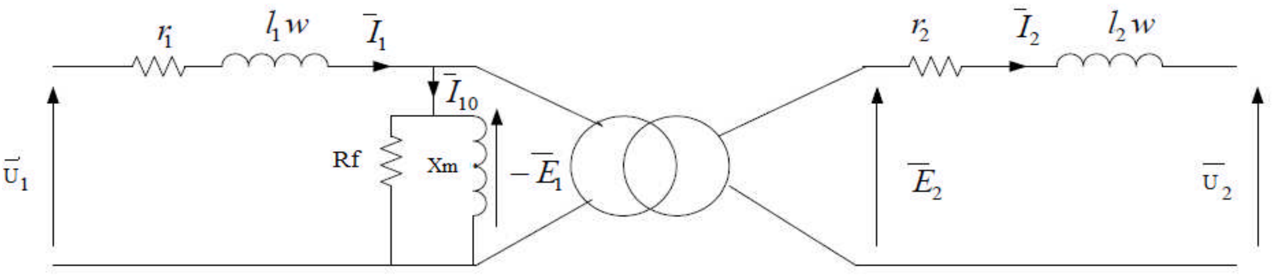


Figure 3 - Equivalent diagram of a real transformer

## 4) Equivalent diagram under the Kapp hypothesis

The **Kapp** hypothesis consists of neglecting the current $\mathbf{I_{10}}$ in front of the current $\mathbf{I_1}$

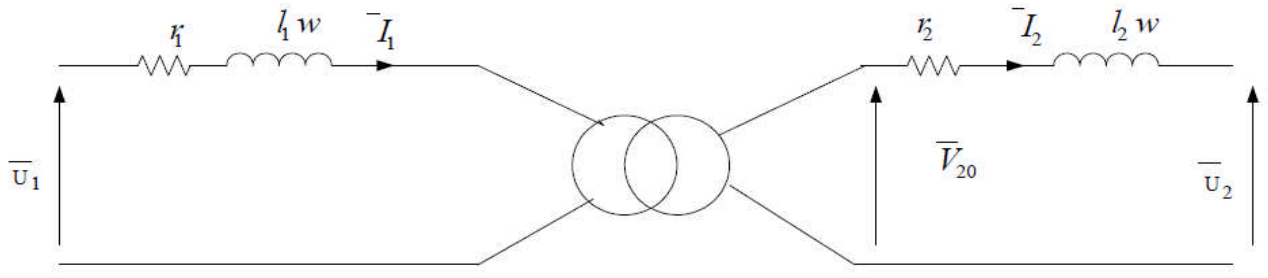


Figure 4 - Equivalent diagram under the Kapp hypothesis

## 5) Equivalent returned to secondary circuit diagram

The impedance **Z1= r1+jlw** can be transferred from the primary to the secondary by multiplying it by m2. This gives the following diagram:

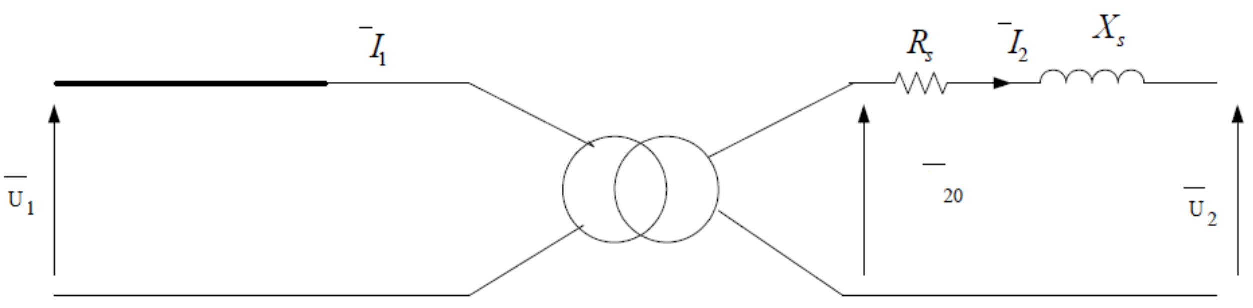


Figure 5 - Equivalent diagram returned to secondary

Where :

$\mathbf{Rs = r_1 + m^2.r_2}$ : the resistance of the transformer returned to the secondary.

$\mathbf{Xs = X1 + m^2.X_2}$: the magnetic leakage reactance returned to the secondary.

## 6) Determine the elements of the equivalent diagram:

Three tests are carried out:

✓ **No-load test (Open circuit test)**

This test consists of applying the rated voltage to the primary winding and measuring the no-load voltage at the secondary, the current and the no-load power absorbed by the primary, as shown in the following diagram:

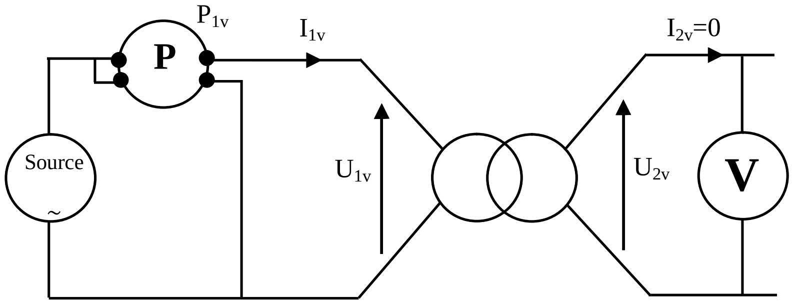


Figure 6 - No-load test

In this case, we can practically determine:

- The transformation ratio $m = \frac{U_{2v}}{U_{1v}}$
- The magnetic circuit resistance $R_f = \frac{U_{1v}^2}{P_f} \approx \frac{U_{1v}^2}{P_{1v}}$.
- The magnetising reactance $X_m = \frac{U_{1v}^2}{Q_f} \approx \frac{U_{1v}^2}{Q_{1v}}$.
- Joule losses are negligible compared with iron losses $P_F \approx P_{1v}$

✓ **Short-circuit test with reduced primary voltage**

A reduced voltage $U_{1cc} \ll U_{1n}$ (rated voltage) is applied to the primary, and $U_{1cc}$is gradually increased from 0 until $I_{2cc} = I_{2n}$.

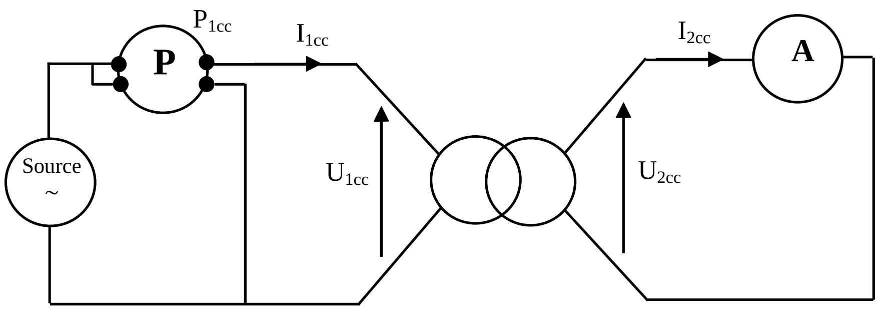


Figure 7- Short-circuit test

Since $U_{1cc} \ll U_{1n} \Rightarrow$ the iron losses during the short-circuit test are negligible and therefore:

$$P_{1cc} = R_s.I_{2cc}^2 \Rightarrow R_s = \frac{P_{1cc}}{I_{2cc}^2}$$

The equivalent diagram brought back to the secondary (short-circuited) is as follows:

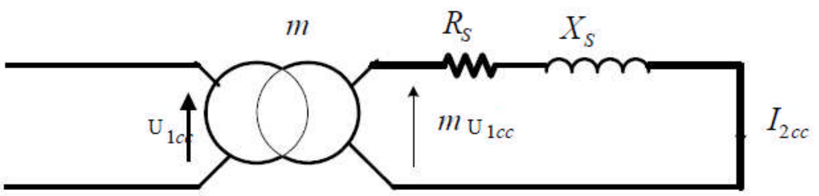


Figure 8- equivalent diagram for short-circuit test

$$Z_s = m\frac{U_{1cc}}{I_{2cc}} \quad \text{and} \quad X_s = \sqrt{{Z_s}^2 - {R_s}^2}$$

Iron losses are negligible compared to joule losses, therefore $P_J \approx P_{1cc}$.

- ✓ **Load test**
  A nominal voltage is applied to the primary.

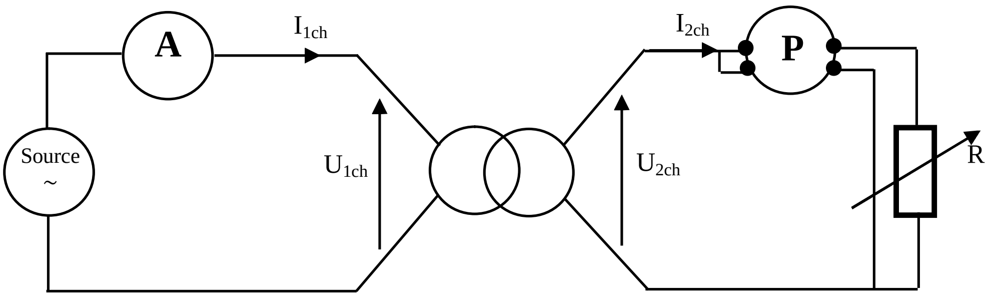


Figure 9 - Load test

Finally, we can calculate the efficiency of the transformer $\eta(\%) = \frac{P_2}{P_1}.100 = \frac{P_2}{P_2+P_f+P_j}.100.$

# IV- Practical part:

## 1. Transformer characteristics

On the transformer, note the following characteristics:
Nominal voltage at the primary **$U_{1n}$** = …………………
Nominal voltage at the secondary **$U_{2n}$** = …………………
Apparent power **$S_n$** = ……………..……

## 2. Nominal currents

Assuming **$S_1 = S_2 = S_n$**, determine the rated primary and secondary currents, **$I_{1n}$** and **$I_{2n}$**..

**$I_{1n}$**= ………………………….….. **$I_{2n}$** = ……………………….……….……..

## 3. Choice of load resistance

Efficiency is calculated from measurements at rated voltages and currents. The load resistor **R** must be chosen so that the transformer operates at rated power.
What is the value of the load resistor **R** connected to the secondary winding to obtain the rated current **$I_{2n}$**?
**R** = …………………….

## 4. Measuring winding resistances: voltammetric method

To verify the simplifying assumptions of the separate loss method, it will be necessary to know the value of the transformer winding resistances. To measure them accurately, the voltammetric method is used.

1. Carry out the following assembly.

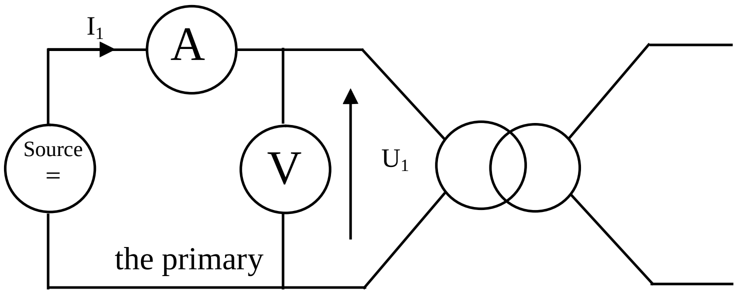


Figure 10

2. Set the power supply to operate at rated current.
3. Read **$U_1$** and **$I_1$**. Deduct the resistance of the primary winding **$r_1$**.

**$U_1$**= ………………… ; **$I_1$**= …………………. ; **$r_1$**= …………………………

**4.** Repeat the operation for the transformer secondary.

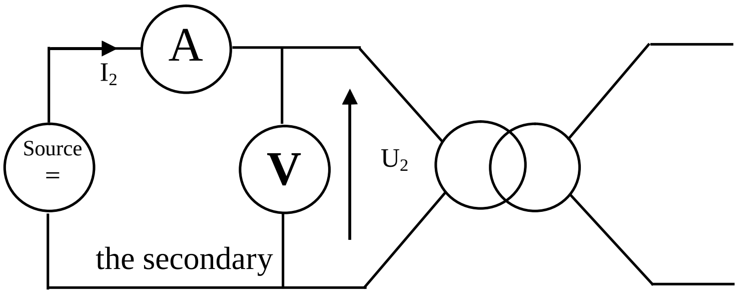


Figure 11

1. Set the power supply to operate at the rated current or, if this is not possible, at the maximum current that the power source can deliver.
2. Read $\mathbf{U_2}$ and $\mathbf{I_2}$. Subtract the resistance of the primary winding r2.

$\mathbf{U_2}$= ………………….. ; $\mathbf{I_2}$= …………………….. ; $\mathbf{r_2}$=……………………….

**Note:**

The resistance of a copper wire changes with temperature. To obtain the most accurate value, it should be measured when 'hot' by passing the rated current through the wire and when the winding has reached its operating temperature.

## 5. No-load test:

This test is carried out at nominal voltage. Since the transformer is operating at no load, the current will be low.

1. Set up the diagram below.

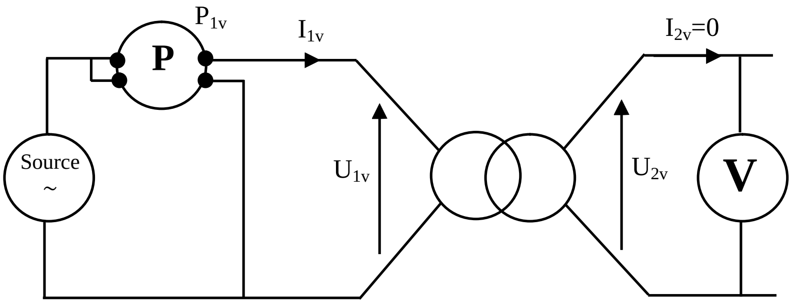


Figure 12

2. Vary the primary voltage from **0 à ….$\mathbf{U_{1n}}$** and plot the curve **$\mathbf{U_{2v}}$=f ($\mathbf{I_{1v}}$)**.

| $U_{1v}$(A) | 40 | 80 | 120 | 160 | 220 |
|---|---|---|---|---|---|
| $I_{1v}$(A) | . | . | . | . | . |
| $U_{2v}$(V) | | | | | |

Table 1

3. Take measurements of the following quantities:

| Greatness | $U_{1n}$(V) | $U_{2v}$ (V) | $I_{1v}$(A) | $P_{1v}$(W(att | $Q_{1V}$ (Var) | Cos ($\varphi_1$) |
|---|---|---|---|---|---|---|
| Measurement | . | . | . | . | . | . |

Table 2

4. From these measurements, complete the following table:

| Formula | the transformation ratio<br>m = | the power factor<br>Cos ($\varphi_1$) = | the iron losses<br>$P_{Fer}$ = |
|---|---|---|---|
| Calculation | . | . | . |

Table 3

5. Calculate the magnetic resistance **Rm** and the magnetic reactance **Xm**.
6. What can we conclude?

## 6. Short-circuit test:

For the short-circuit test, it is necessary to work at rated current and therefore at a very low voltage (a few volts).

1. Set up the diagram below.

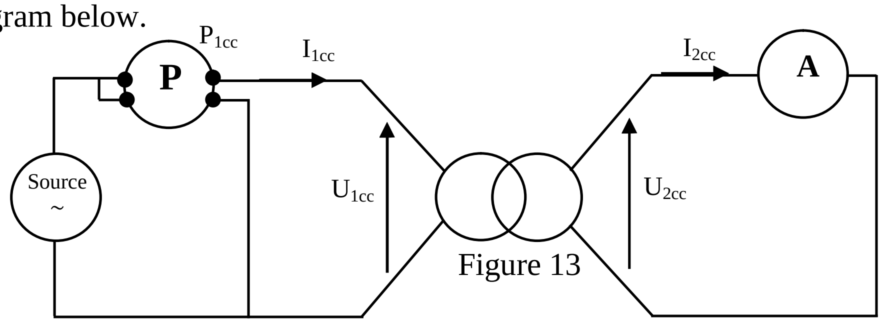


Figure 13

2. Take the necessary measurements to plot the curve: $\mathbf{P_{1CC} = f\,(I_{2CC}^2)}$.

| | | | | | |
|---|---|---|---|---|---|
| $U_{1cc}$(V) | . | . | . | . | . |
| $I_{2cc}$(A) | . | . | . | . | . |
| $P_{1cc}$(Watt) | | | | | |

Table 4

3. Calculate the secondary resistance **Rs** (graphically).
4. Measure the following quantities:

| Greatness | $U_{1cc}$(V) | $I_{1cc}$(V) | $I_{2cc}$(A) | $P_{1cc}$(Watt) |
|---|---|---|---|---|
| Measurement | . | . | . | . |

Table 5

5. From these measurements, complete the following table:

| Formula | Joule or copper losses<br>Pj= | Resistance reduced to secondary level<br>Rs= | impedance reduced to secondary level<br>Zs= | reactance reduced to secondary level<br>Xs= |
|---|---|---|---|---|
| Calculation | . | . | . | . |

Table 6

6. What can we conclude?

## 7. Load test:

Make the following assembly : **$U_{1ch}$=$U_{1n}$**

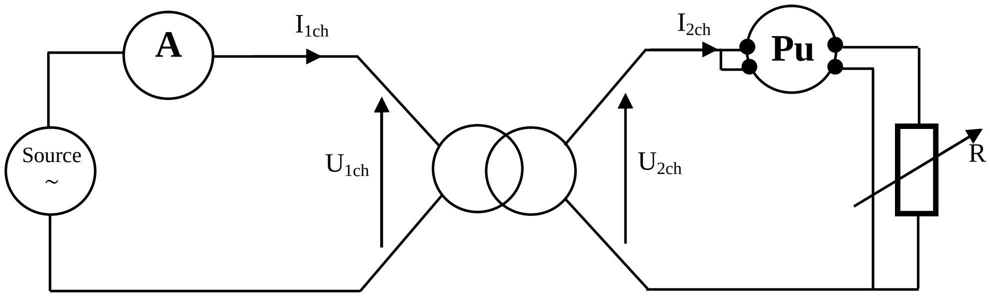


Figure 14

1. For **0 ≤ $I_{2ch}$≤$I_{2n}$**, record **$I_{1ch}$**, **$U_{2ch}$** ,**$P_{2ch}$** and complete the following table:

| | | | | | | |
|---|---|---|---|---|---|---|
| $I_{1ch}$ (A) | | | | | | |
| $I_{2ch}$ (A) | 1 | 1.5 | 2 | 2.5 | 3 | 3.2 |
| $U_{2ch}$ (V) | | | | | | |
| $P_{2ch}$ (W) | | | | | | |
| $Pj_{ch}=Rs.\ I_{2ch}^{2}$ | | | | | | |
| $P_{1ch}=P_{2ch}+P_{fer}+Pj_{ch}$ | | | | | | |
| η (%) = ($P_{2ch}$ / $P_{1ch}$)*100 | | | | | | |

Table 7

2. Plot and interpret the curve **η=f ($I_{2ch}$)**.
3. Give the value of **$I_{2ch}$** ch so that **η** is maximum.
4. Draw conclusions.

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| *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 |

*******************************************************************************************

# *PW n°05 : Direct current machines*

Duration : $1^h30$.

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

Report prepared by:

| **Last Name** | **First Name** | **Group** | **S/Group** | **Final Note** |
|---|---|---|---|---|
| - | - | - | - | - |
| - | - | - | - | - |
| - | - | - | - | - |
| - | - | - | - | - |

## 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.**

Person in charge of practical work: Dr ROUABHI.R

## I- Aim of the manipulation:

General study of a direct current machine for both generator and motor modes of operation.

## II- Equipment used:

- DC voltage sources.
- Rheostats.
- Measuring instruments (voltmeters, ammeters, multimeters).
- Separately excited generators.
- Separately excited motors.

## III- Theoretical reminder:

### 1. Description :

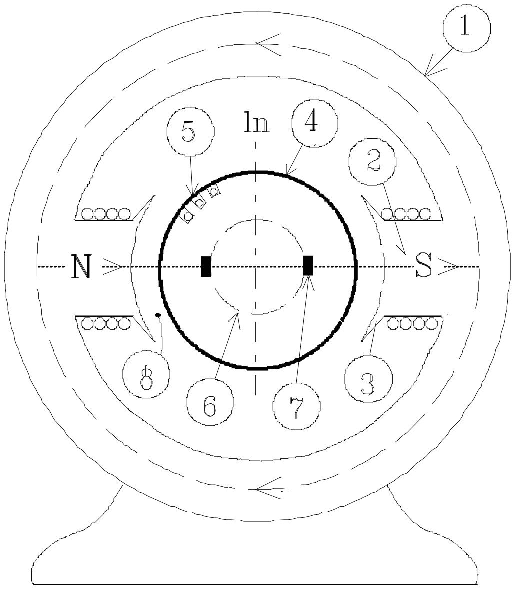


Figure1

It consists of 2 main parts:

- The fixed part : Stator or inductor
- The moving part: Rotor or armature

1: Machine frame. It supports the fixed parts (poles). It closes the magnetic circuit (dotted field line).

2: Main poles (laminated). The field is generated by the magnetising coils * field circuit (**Iex**) or by permanent ferrite magnets. **Ln** is the neutral line where the magnetic field is cancelled and then reversed.

3: Laminated poles. They make it possible to increase the field area.

4: Laminated rotor.

5: Notches. These contain the conductors that are the seat of the induced **e.m.f** when this part rotates in the field: induced circuit.

6: The commutator (copper blades insulated with mica), located at the end of the rotor and mounted on the same shaft.

7: Brushes: These are fixed to the frame by means of the brush holder. They are made of carbon and rub against the commutator. They are located on the axis of the main poles.

8: The air gap.

armature inductor

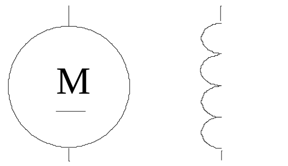



Figure2: Direct current machine symbol

## 2. Principle and reversibility of the DC machine

### 2.1. A reminder of electromagnetism:

**-Lenz's Law:** An induced e.m.f. is created in a conductor subjected to a flux variation (here a conductor moving in the field e=-dφ/dt ou <e>=│ΔΦ/Δt│. The direction of this e.m.f. is given by the rule of the 3 fingers of the left hand.

**-Laplace force:** An electromagnetic force is created on a conductor carrying a current and placed in a magnetic field: the direction of this force is given by the rule of the 3 fingers of the right hand:

$\vec{F} = I\vec{l} \wedge \vec{B}$ et $F = I\ell B \sin(I\vec{l}, \vec{B})$

### 2.2. Operating principle and reversibility:

**Generator**

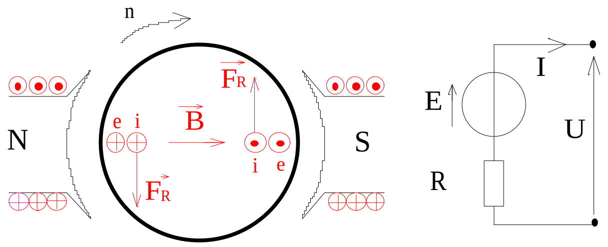



Figure 3

Rotation creates an induced **e.m.f** which supplies a current. This current creates electromagnetic forces and a resistive torque.

The polarity of the DC machine (generator) is reversed:

- The direction of rotation
- The exciting current **Iex** (F and B).

**Motor**

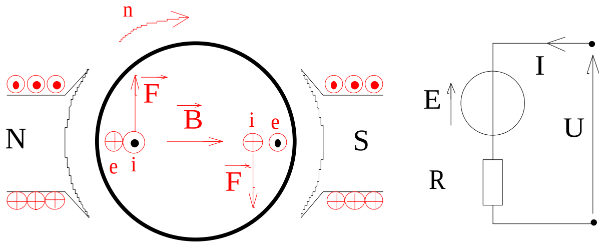



Figure 4

The power supply creates a current which generates electromagnetic forces and a motor torque. Rotation occurs and induced **e.m.f** is created.

Pe = EI $\Rightarrow$Pm= TΩ

The direction of rotation of the DC machine (motor) is reversed by inversion:

- The field current **Iex**.

-The supply voltage.

## 3. Role of the collector

It rectifies the **e.m.f** at the terminals of a winding to obtain an always positive **e.m.f.**

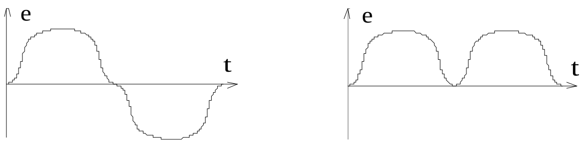



Figure 5

## 4. Basic characteristics of the DC machine

### 1. Induced electromotive force E:

$E=\frac{N}{2}\Delta\Phi/\Delta t = \frac{N.2.\Phi}{2.1/n} = N.n.\Phi = \frac{N.\Omega.\Phi}{2\pi} = K.\Phi.\Omega$ .  $\boxed{E= K.\Phi.\Omega}$ : general relationship

If the flux **Φ** is constant (constant excitation current (**Iex**) or permanent magnet), the **e.m.f** is proportional to the speed n $\boxed{E = k.n}\Rightarrow$ E/E'=n/n'.

### 2. Power (Pe) and electromagnetic torque (Te) :

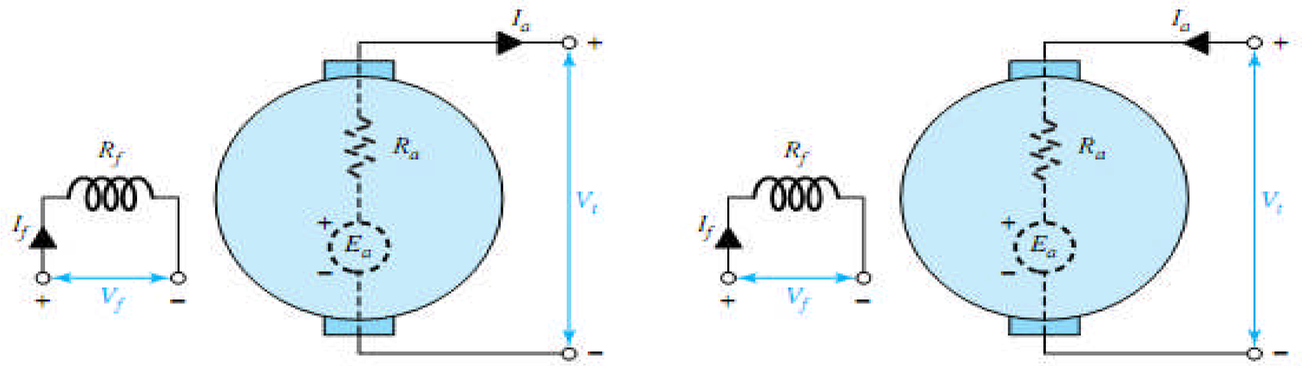
Electrical power is converted into mechanical power and vice versa. This is electromagnetic power: Pe=E.I=Te.Ω

Te = Pe/Ω = E.I/Ω= K.Φ.I.

Te in Nm ,

Pe in W ,  Ω in rad/s

## 3. Mode of operation:




**Generator U= Ea-Ra.Ia** Figure 6 **Motor Ea+Ra.Ia**

## IV- Practical part:

## 1. Separately excited no-load generator:

- **Variation of the electromotive force e.m.f. with excitation: E(Iex). =cte=1500rpm**

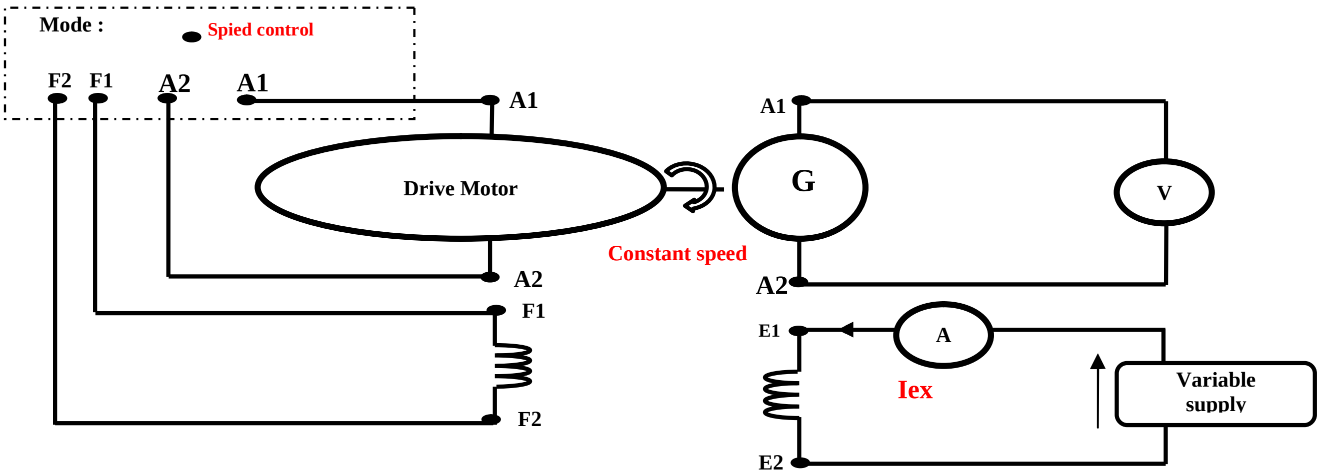



Figure 7

The armature is no-load Uv = E

-The field winding, the excitation circuit, behaves as a resistor and Vex=(Rh+rex)Iex

1) Make the circuit shown in figure 7.

2) Complete the following table.

| Iex(A) | 0 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $U_V$=E(V) Iex ↗ | | | | | | | | |
| $U_V$=E(V) Iex ↘ | | | | | | | | |

3) Plot the curve E= f(Iex) in Figure 8.

4) Interpret the curve E= f(Iex) and conclude.
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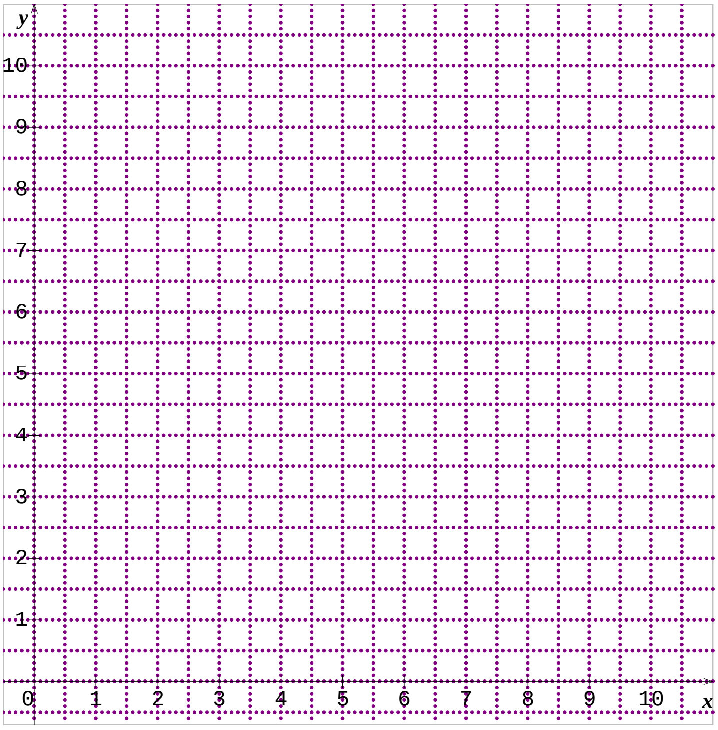


Figure 8

5) determine the value of the remanent electromotive force.
……………………………………………………………………………………………………
…………………………………………………………………………Er =……………….V.

## 2. Separately excited no-load motor:

➢ **Variation of the rotation speed n (rpm) with the supply voltage U(V):**

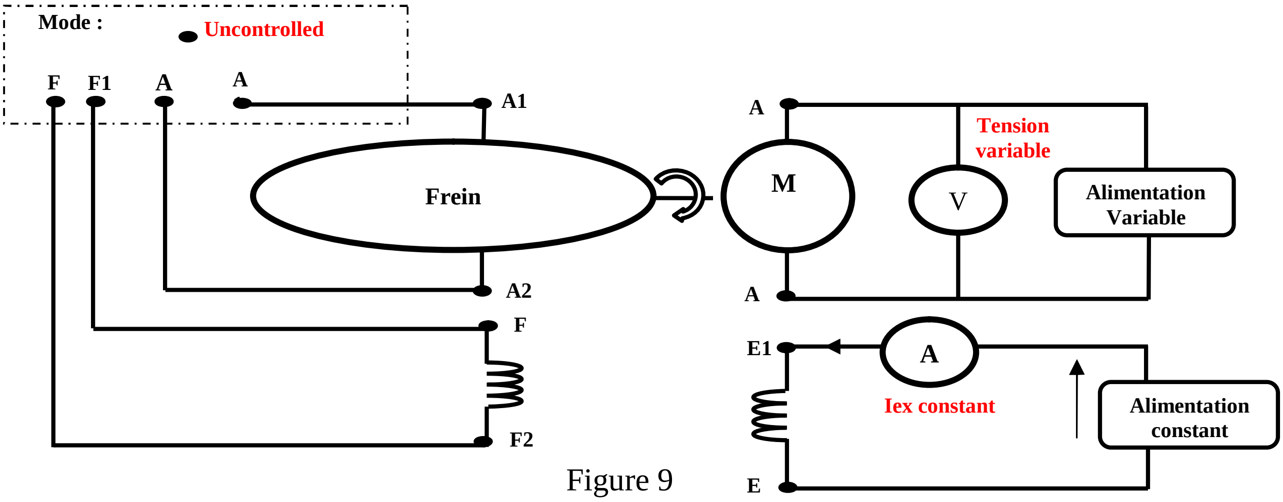


Figure 9

1) Carry out the assembly as shown in figure 9. Iex = 0.16A = cte
2) Complete the table above

| U(V) | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|
| n (rpm) | | | | | | | | | |

3) Plot the curve n= f(U) in Figure 10..

4) Interpret this graph and find the expression for the function f.

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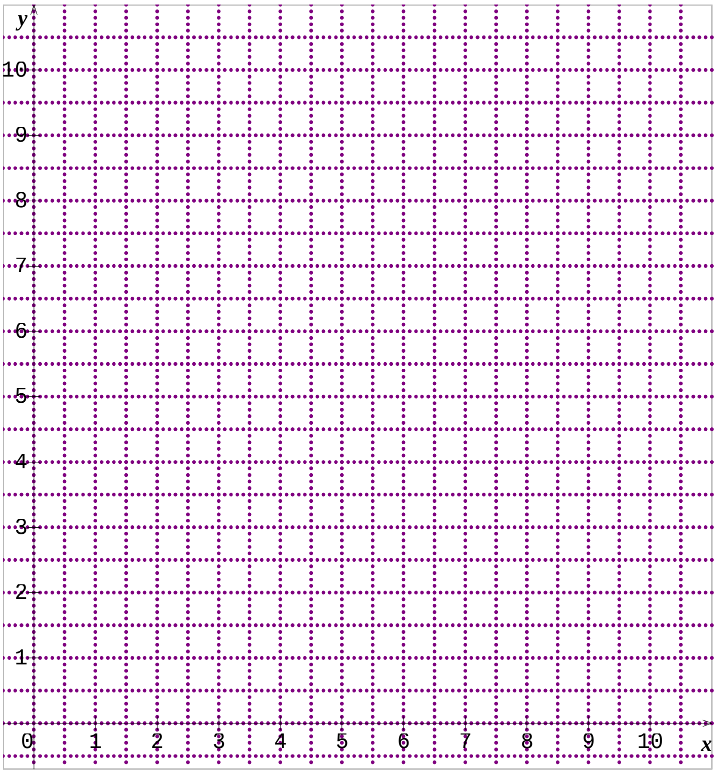


Figure 10

**Conclusion** :

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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 Electronics 1* | أعمال تطبيقية في الالكرونيك الأساسية 1 |

************************************************************************************************************************

# *PW n°01 : Introduction to Equipment and Essential Reminders*

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.**

Person in charge of practical work: Dr ROUABHI.R

# ***PW n°01*: Introduction to Equipment and Essential Reminders**

## I. Purpose of the Experiment

The primary objective of this laboratory exercise is to familiarize students with electrical components, including resistors, measuring instruments, and the wiring of direct current (DC) electrical circuits. We will specifically examine the laws relating charge and potential difference for resistors, as well as practical applications of these laws in measuring electric current.

## II. Theoretical Overview

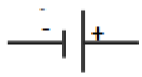
### 1. Measuring and Testing Instruments

A measuring instrument (or measuring device) is a tool designed to experimentally obtain values that can be attributed to a specific physical quantity. The device used to measure the potential difference between two points in a circuit is called a voltmeter. An ammeter is employed to measure the current in a branch of the circuit, while an ohmmeter is used to measure the resistance of a portion of the circuit. Additionally, potential differences can be analyzed using an oscilloscope, which we will discuss later. Each measuring instrument features two probes—wires extending from the device that must be connected to the circuit appropriately to obtain accurate measurements. The measuring equipment available in the measurement laboratory at the Faculty of Technology, University of M'sila, is detailed in the attached appendix.

- Digital DC Power Supply with Analog and Digital Display
- Analog Voltmeter
-Analog Ammeter
- Digital Multimeter
- Oscilloscope
- Function Generator (Low-Frequency Generator, GBF)
- Test Bench
- Cables and Probes

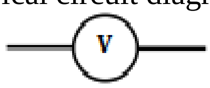
### 2. DC Power Supply

A direct current (DC) power supply is a device capable of providing or dissipating electrical energy. Educational power supplies are specifically designed for laboratory use. These power supplies feature fixed or adjustable current or voltage outputs, allowing users to limit the current or voltage to a predetermined level. This capability helps prevent circuit interruption during testing (see Appendix A).

The symbol used to represent a DC power supply in an electrical circuit diagram is as follows: 

### 3. The Voltmeter

A voltmeter is an instrument used to measure the potential difference between two points in an electrical circuit. The symbol used to represent a voltmeter in an electrical circuit diagram is as follows:



The voltmeter (see Appendix D) measures the potential difference between two arbitrary points, a andb, in a circuit (Figure 1). Therefore, one probe must be connected to each of these points, and the voltmeter is placed in parallel with the branch or branches of the circuit located between points a and b.

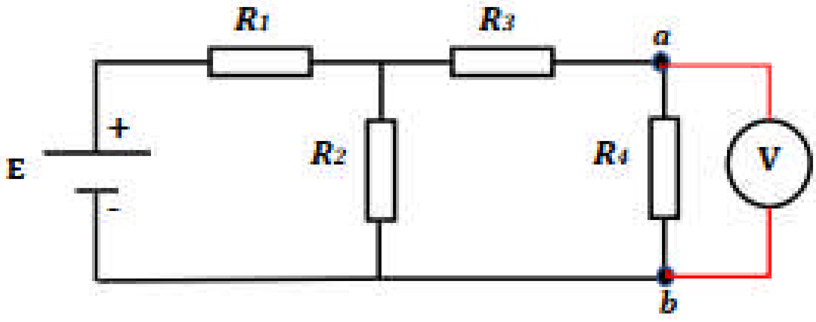



Figure 1: Voltage Measurement Using a Voltmeter

### 4. The Ammeter

An ammeter is an instrument used to measure the electric current flowing through a circuit. The symbol used to represent an ammeter in an electrical circuit diagram is as follows: 


The ammeter (see Appendix D) measures the current flowing through a branch of the circuit, and it must be connected in series with that branch to ensure that the same current flowing through the branch also passes through the ammeter. To measure the current, the branch must first be disconnected to insert the ammeter into the circuit. In Figure 2, the ammeter is connected in series with resistor R4 and as a result, measures the current flowing through R4

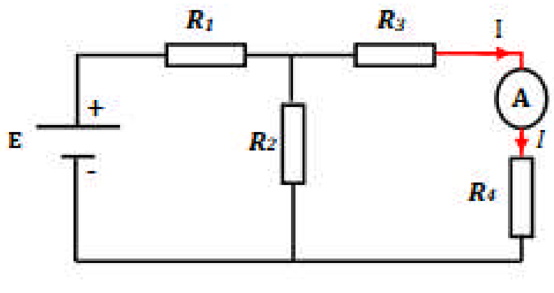
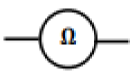



Figure 2: Current Measurement with Ammeter.

### 5. The Ohmmeter

The symbol used to represent an ohmmeter in a circuit is as follows: 


Unlike voltmeters and ammeters, the ohmmeter is an active device; it contains an internal battery of known value that supplies current to the circuit being measured. To measure the value of a resistor or a combination of resistors, both probes of the ohmmeter must be connected to the terminals of the resistor or resistive combination, ensuring that it is not receiving current from the rest of the circuit. If the circuit were still connected, the current from the circuit would combine with the current supplied by the ohmmeter, leading to an inaccurate measurement.

Figure 3(a) illustrates a correct method for measuring the resistance R4 in the circuit shown in Figure 2. Note that only one of the connections between R4 and the rest of the circuit has been broken. While it is possible to disconnect both connections, it is not necessary; interrupting the branch at any point is sufficient to prevent current from flowing through R4.

Figure 3(b) shows a correct method for measuring the combined resistance of resistors R3 and R4 connected in parallel.

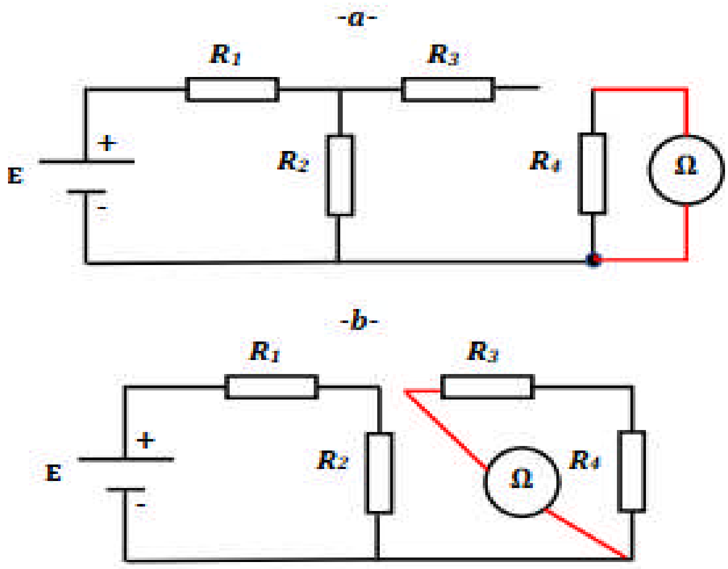



Figure 3: Resistance Measurement in an Electrical Circuit

**6. The Multimeter**

In practice, the various instruments described above are often combined into a single device known as a multimeter (see Appendix C). This device can be configured to function as a voltmeter, ammeter, or ohmmeter, and it allows the selection of different sensitivity ranges. Analog measuring devices are typically constructed from a galvanometer, which operates based on magnetic effects. However, these analog devices have largely been replaced by digital displays that are generally less expensive, more robust, and more precise. Digital multimeters do not rely on galvanometers; instead, they use electronic circuits with transistors to facilitate direct measurement of potential difference.

***Note:** For alternating currents, multimeters display effective values for both current and voltage, not peak or maximum values.*

## 7. The Oscilloscope

While it can measure a continuous potential difference, the oscilloscope is particularly well-suited for studying alternating voltages. It allows not only the measurement of amplitude but also the observation of the waveform over time (see Appendix B). The oscilloscope consists of a cathode ray tube (CRT) housed in a glass envelope containing a vacuum (see Figure 4). Electrons are emitted from a heated cathode and accelerated by a high voltage applied to the anode, which has a small aperture. The electron beam is directed onto a fluorescent screen, where it creates a visible trace or spot.

Before reaching the screen, the electron beam passes between two pairs of plates to which a potential difference can be applied, creating an electric field between them. Consequently, a force acts on the electrons. One pair of plates is oriented vertically and deflects the beam horizontally, while the other pair is horizontal and deflects the beam vertically. By varying the voltages on the plates, the spot created by the electrons on the screen moves, tracing a path that can be observed.

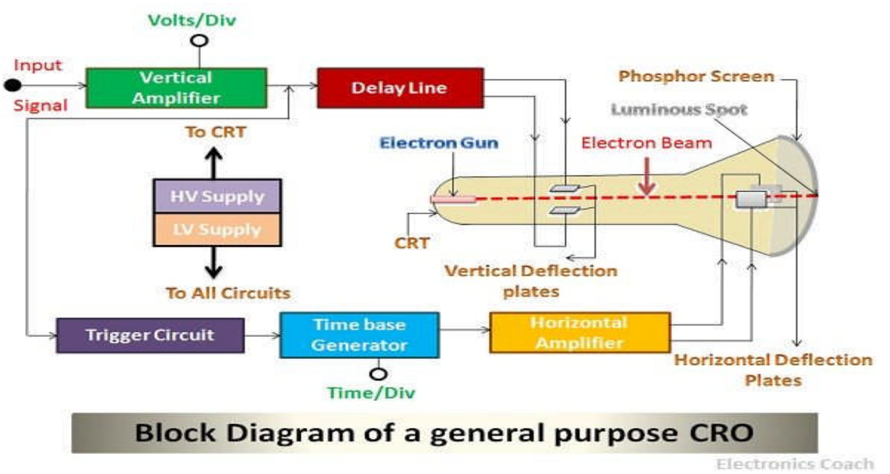



Figure. 4 : Schéma synoptique d'un oscilloscope.

The most common mode of operation for the oscilloscope involves applying a sweep voltage to the vertical plates. This causes the spot to deflect from left to right at a constant speed, returning quickly to the left when it reaches the right edge of the screen. The potential difference to be observed is applied between the horizontal plates, resulting in vertical deflection of the spot. The combination of these two deflections allows for the observation of voltage variation over time on the screen.

## 8. The Function Generator

A function generator, also known as a low-frequency generator (GBF), is a device used in electronics for testing or troubleshooting electronic circuits. A GBF can produce signals at desired frequencies in the form of sine waves, square waves, or triangular waves. These signals can be observed using an oscilloscope through a simple electrical setup.

### 9. The Breadboard

Before soldering a circuit, it is advisable to verify that it functions correctly. A breadboard is an excellent tool for testing a circuit without the need for soldering, allowing for quick checks to ensure there are no errors in the assembly. A breadboard consists of an insulating plastic board dotted with numerous holes. These holes are spaced 2.54 mm apart, which the standard is spacing for electronic components used in our assemblies. Using a breadboard is straightforward once one understands how the holes are interconnected (see Figure 5).

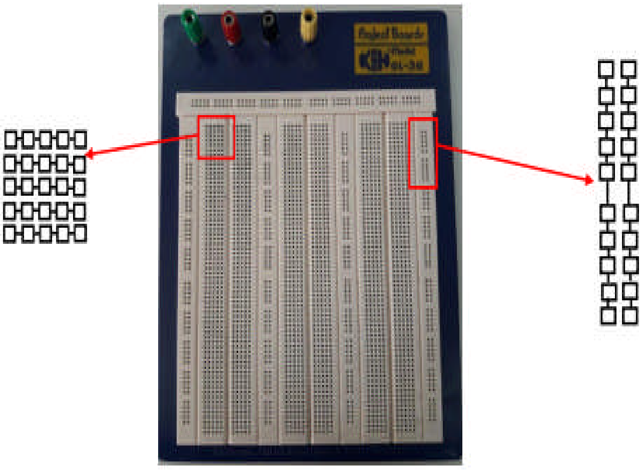


Figure 5: Breadboard

### 10. Introduction to Resistance

A resistor is an electronic or electrical component whose primary characteristic is to oppose the flow of electric current, measured in ohms. Electrical resistance is one of the fundamental components in the field of electricity. The term "resistance" primarily refers to a physical property, but it has also come to denote a specific type of component. Some prefer to call it a "resistive device."

### 10.1. Identification

To determine the ohmic value of a resistor, one must identify the color bands present on the resistor (see Figure 6) and associate them with the universal color code. The international standard IEC 60757, titled "Color Code Designation" (1983), defines a color code that is applied to resistors, indicating their resistance values.

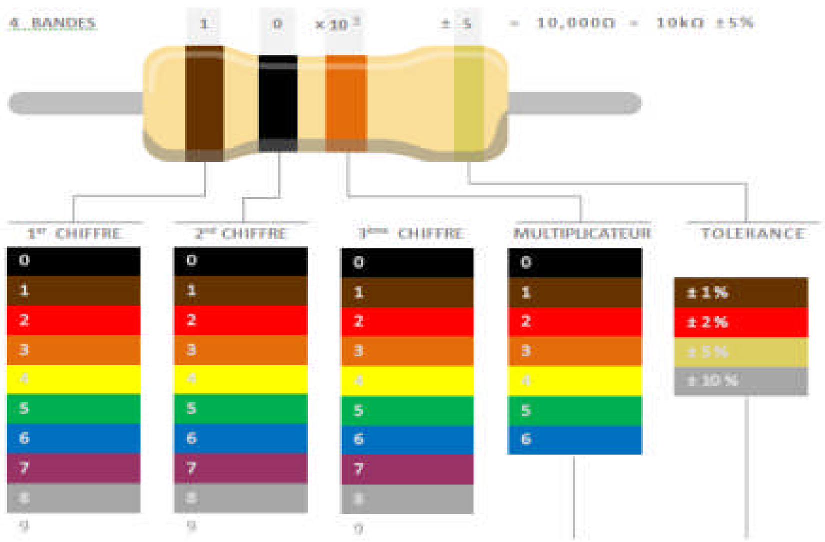



Figure 6: Resistor Color Code

### 10.2. Series Connection of Resistors

When two or more resistors are connected in such a way that the same current flows through each of them successively, they are said to be connected in series. A defining characteristic of series connections is that the current passing through each resistor is identical; thus, all resistors in a series connection carry the same current.

Example: The equivalent resistance R of two resistors connected in series (see Figure 7) can be easily calculated. In this case, both resistors experience the same current of intensity I.

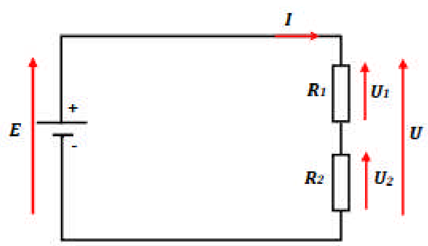



Figure 7: Resistors in Series

Using Ohm's Law, we can express: U1=R1*I U2=R2*I

The voltage U across the terminals of the two resistors R1 and R2 which are connected in series, is equal to the sum of the voltages across each resistor: U=U1+U2 =R1*I+R2*I= (R1+R2)*I, where R1+R2=R

The resistance R represents the equivalent resistance of the two resistors R1 and R2 connected in series. Consequently, for N resistors arranged in series, the equivalent resistance can be expressed as: **R=R1+R2+R3+R4+…….RN**

### 10.3. Parallel Connection of Resistors

In this type of configuration (see Figure 8), each of the two resistors R1 and R2 has one terminal connected to the positive (+) terminal of the power supply and the other terminal connected to the negative (-) terminal. As a result, both resistors experience the same voltage provided by the power supply. This condition is a defining characteristic of parallel connections, where the voltage across multiple components connected in parallel is always the same.

**Example:** Let us calculate the equivalent resistance R of the two resistors connected in parallel, as shown in figure 8.

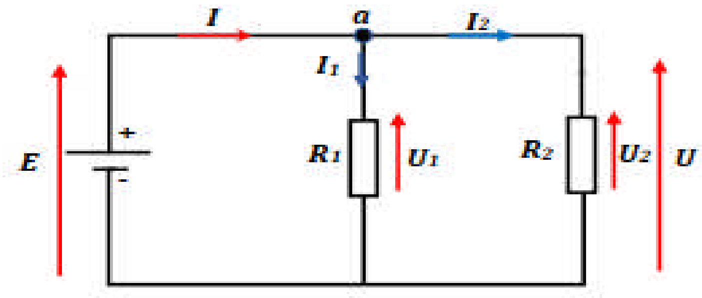



Figure 8: Resistors in Parallel

The two resistors R1 and R2 are subjected to the same voltage: U=U1+U2

The sum of the currents entering a junction is equal to the sum of the currents leaving that junction (known as Kirchhoff's Current Law). In junction of Figure 8, we have: I=I1+I2

By applying Ohm's Law to each of the resistors, we find:

U1=R1*I1 and U2=R2*I2; I1=U1/R1 and I2=U2/R2

We have: I=I1+I2= U/R1+U/R2= U(1/R1+1/R2)

We can deduce the equivalent conductance, denoted as 1/R, as follows: $\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2}$

Consequently, for N resistors connected in parallel, the equivalent resistance can be expressed as:

$$\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2} + \cdots \dots \dots + \frac{1}{RN}$$

## III. Practical part

### 1. Personal Work

1. Consider the following electrical circuit:

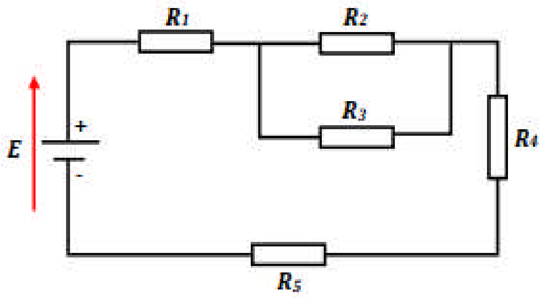



Figure 9

a. Redraw this circuit by including an ammeter to measure the current flowing through the resistor R3

b. Redraw the initial circuit by including a voltmeter to measure the voltage drop across resistors R4 and R5

c. Redraw the initial circuit by including an ohmmeter to measure the resistance R2

2. Consider the following circuit:

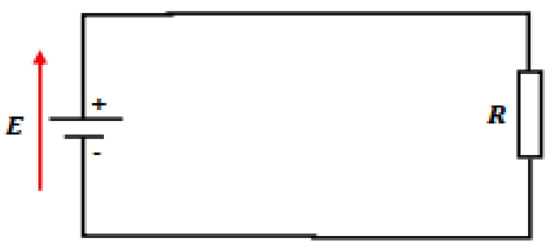



Figure 10

We aim to simultaneously measure the current flowing through resistor R using an ammeter and the voltage difference across R with a voltmeter.

Create a schematic diagram of the setup to be implemented.

The figure below illustrates the screen of an oscilloscope operating in sweep mode, displaying the variation of a sinusoidal voltage V(t) as a function of time. Considering the indicated voltage and time scales on the figure:

a. What are the amplitude, period, and frequency of this voltage?

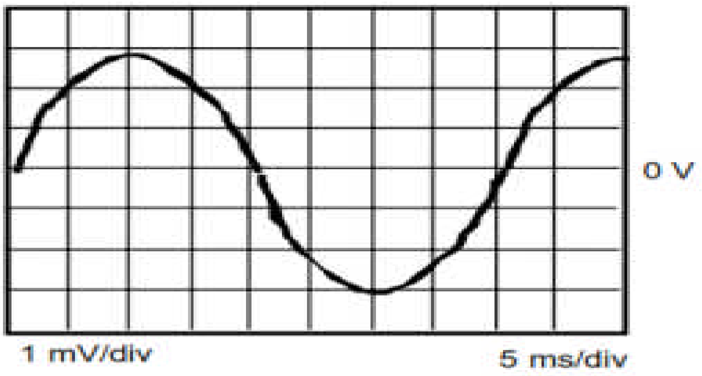



Figure 11

**2. In-Person Work**

1. **Setup 1**

a. Construct the circuit as shown in the following figure, using the following resistor values: R1=1 kΩ, R2=4.7kΩ; R3=10 Kω

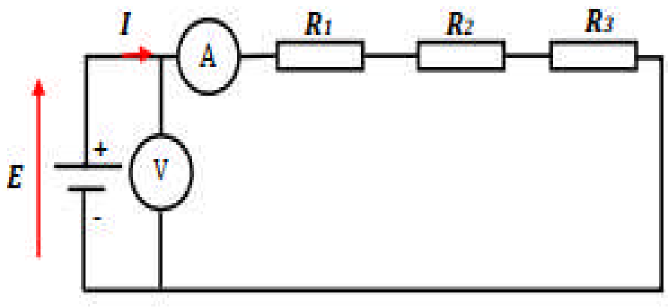



Figure 12

b. Measure the resistance values for R1,R2 and R3 using:

- The color code.
- An ohmmeter.

c. Using a voltmeter, measure and adjust the voltage E to 10 volts.

d. Using an ammeter, measure the current I.

e. Measure the following voltage drops: U1 a cross R1; U2 across R2; and U3 across R3 Verify the relationship:

E=U1+U2+U3,

f. Deduce the values of resistances R1R2 and R3 from the measurements obtained.

Compare these values with those found in part b.

2. **Setup 2**

   a. Construct the circuit as shown in the following figure, using the resistor values: R1=1 kΩ ,R2=4.7 KΩ and R3=10 kΩ

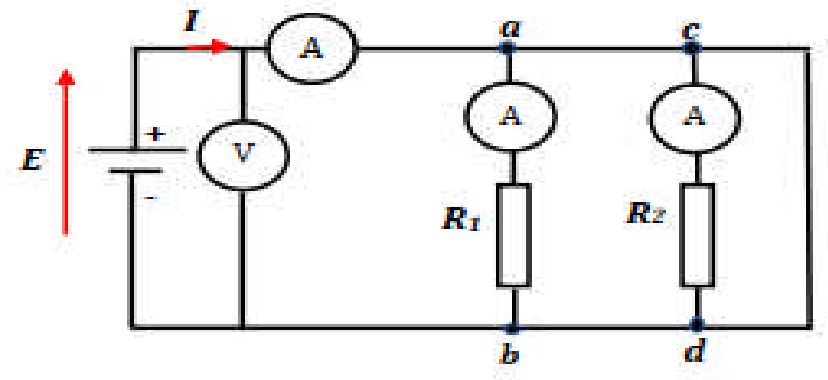



Figure 13

b. Using a voltmeter, measure and adjust the supply voltage E to 10 Volts.

c. With the voltmeter, verify that the voltage across each branch (between pointsab and cd) is equal to the supply voltage. Confirm the relationship: E=U1(ab)=U2(cd)

d. Utilize an ammeter to measure the current at the output of the power supply I, as well as the current in each branch ( ab and cd). Verify the law of conservation of charge at the node.

**3. Setup 3**

**a.** Set up the wiring as shown in the diagram below:

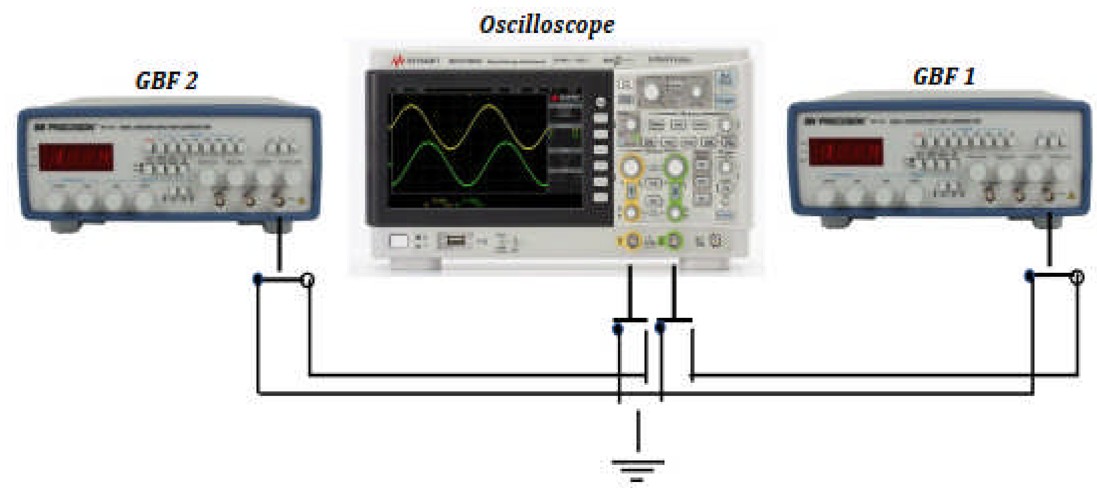



Figure 1'

**b.** Using GBF 1, generate a sinusoidal signal.

**c.** Using GBF 2, generate a triangular signal.

**d.** Visualize both signals on the oscilloscope.

**e.** Adjust the amplitude of the sinusoidal signal to 5V and the amplitude of the triangular signal to 10V, ensuring both signals have a period $T_{of}$ 0.001s.

**f.** Using the oscilloscope, create a phase shift of T/2 between the two signals.

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*******************************************************************************************************************

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# *PW n°02: Superposition Theorem*

Duration: $1^h30$.

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

Report prepared by:

| Last Name | First Name | Group | S/Group | Final Note |
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| - | - | - | - | - |
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| - | - | - | - | - |
| - | - | - | - | - |

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  - **Last Name and first name of the main writer.**
  - **Last Names and first names of the WP participants.**
  - **Preparation and work in manuscript.**

Person in charge of practical work: Dr ROUABHI.R

## *PW n°02:* Phases Superposition Theorem

## I. Objective of the Experiment

This experiment aims to analyze circuits containing multiple voltage or current sources by isolating the effect of each source individually. This method simplifies the problem-solving process, providing a clear understanding of how each source influences the overall circuit behavior.

## II. Theoretical Background

### 1. Superposition Theorem

The superposition theorem provides a systematic way to analyze complex circuits by considering one energy source at a time while deactivating the others. The results from each individual source are then combined to determine the overall voltage or current.

-**Statement 1**: The total voltage between two points in a circuit with multiple sources equals the algebraic sum of the individual voltages produced by each source acting alone.

- **Statement 2**: The total current in a branch with multiple energy sources equals the algebraic sum of the individual currents generated by each source acting independently.

### 1.1. Principle of Superposition

According to the principle of superposition, the total current (I) in a branch or voltage (U) across two points is the algebraic sum of the contributions from each source, assuming that only one source is active at a time. To implement this theorem:

**1. Deactivate** all sources except one, replacing voltage sources with short circuits and current sources with open circuits.

**2. Calculate** the resulting current or voltage for the active source.

**3. Repeat** this process for each source, then sum the individual contributions to obtain the total current or voltage.

For a circuit with (N) generators:

- **State 1**: All sources are deactivated except generator 1 → Compute ($I_1$).

**- State 2:** All sources are deactivated except generator 2 → Compute ($I_2$).

- **State N**: All sources are deactivated except generator (N) → Compute ($I_N$).

The overall **voltage** between two points is:

$U=U_1+U_2+\cdots+U_N$

Similarly, the total **current** in a branch is:

$I=I_1+I_2+\cdots+I_N$

This method ensures accurate analysis by accounting for the effect of each source individually, making it particularly effective for circuits with complex configurations.

## *PW n°02:* Phases Superposition Theorem

**Remark:**

Deactivating a generator refers to the process of treating it as non-operational:

**- For a voltage source:** This involves setting the voltage across its terminals to zero, which effectively means replacing the ideal voltage source with a short circuit.

**- For a current source:** This entails considering the output current to be zero, accomplished by replacing the current source with an open circuit.

These procedures are essential for accurately applying the superposition theorem, enabling a detailed analysis of each generator's contribution to the overall behavior of the circuit.

**Example:** Consider the circuit illustrated below:

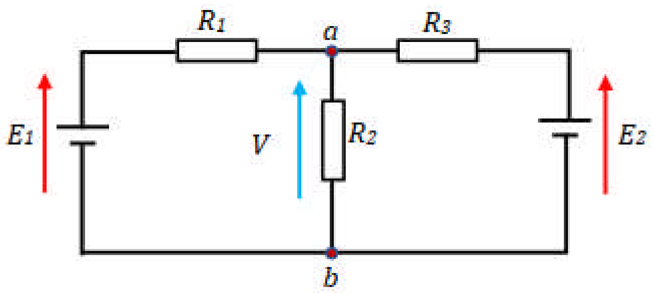


Figure.1

In this example, we will apply the superposition theorem to analyze the contributions of each generator independently.

According to the superposition theorem, the voltage V between points a and b is: $\mathbf{V=V_1+V_2}$

Where:

- V1 is the voltage between points a and b when E1 acts alone (with E2 neutralized).
- V2 is the voltage between points a and b when E2 acts alone (with E1 neutralized).

**a. Calculate V1**

By neutralizing E2, the circuit in Figure 1 will appear as follows:

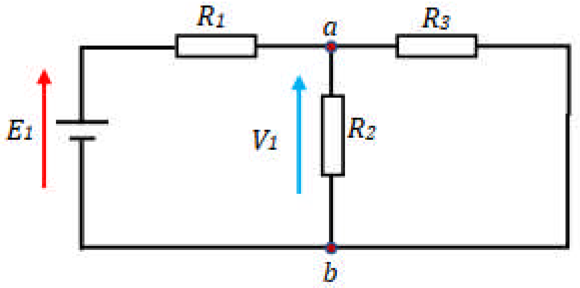


Figure.2

In this configuration, you can now calculate the voltage **V1** across points points a and b based on the remaining components in the circuit.

To calculate the voltage **V1**, we must first determine the equivalent resistance between the two points a and b (the equivalent resistance of the two resistors R2 and R3 which are in parallel):

$$\frac{1}{Req1} = \frac{1}{R2} + \frac{1}{R3}$$

Once $Req1$ is calculated, you can proceed to determine V1using the appropriate voltage division or Ohm's Law techniques.

Thus, the circuit can be simplified to the following:

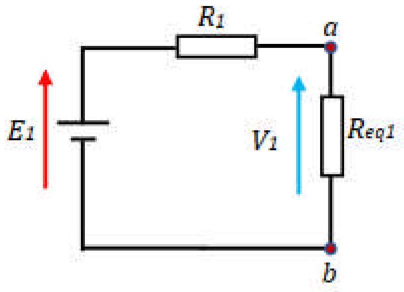


Figure.3

By using the concept of a voltage divider, we find that:

$$V1 = E1\frac{Req1}{Req1 + R1}$$

**b. Calculate V2**

By neutralizing E1, the circuit in Figure 1 will appear as follows:

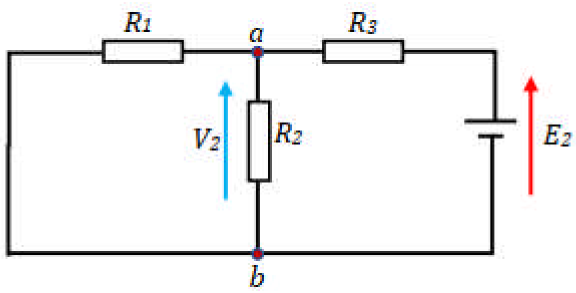


Figure.4

To calculate the voltage **V2**, we must first determine the equivalent resistance between the two points a and b (the equivalent resistance of the two resistors R1 and R2 which are in parallel):

$$\frac{1}{Req2} = \frac{1}{R1} + \frac{1}{R2}$$

Once $Req2$ is calculated, you can proceed to determine V2using the appropriate voltage division or Ohm's Law techniques.

Thus, the circuit can be simplified to the following:

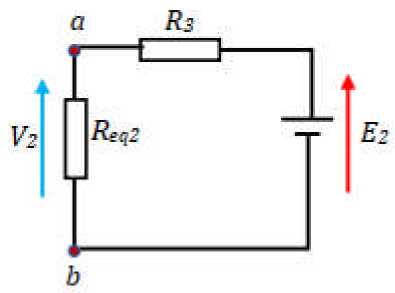


Figure.5

By using the concept of a voltage divider, we find that:

$$V2 = E2\frac{Req2}{Req2 + R3}$$

Finally, the voltage **V** between the two points a and b is equal to the algebraic sum of the two voltages **V1** and **V2:**

$$V = V1 + V2 = E1\frac{Req1}{Req1 + R1} + E2\frac{Req2}{Req2 + R3}$$

## III. Experiment Procedure

### 1. Individual Work

**a.** Using Proteus (see Appendix E), construct the circuit shown below:

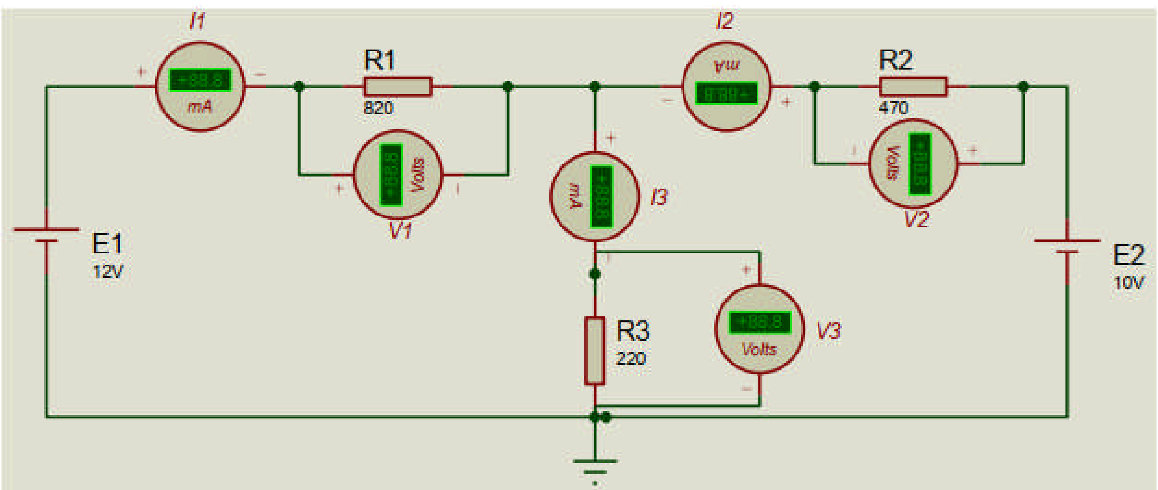


Figure.6

b. Conduct the circuit simulation and complete the table below:

| V1 (V) | V2 (V) | V3 (V) | I1(mA) | I2 (mA) | I3 (mA) |
|---|---|---|---|---|---|
| | | | | | |

c. Short-circuit the voltage source E2 to obtain the following circuit:

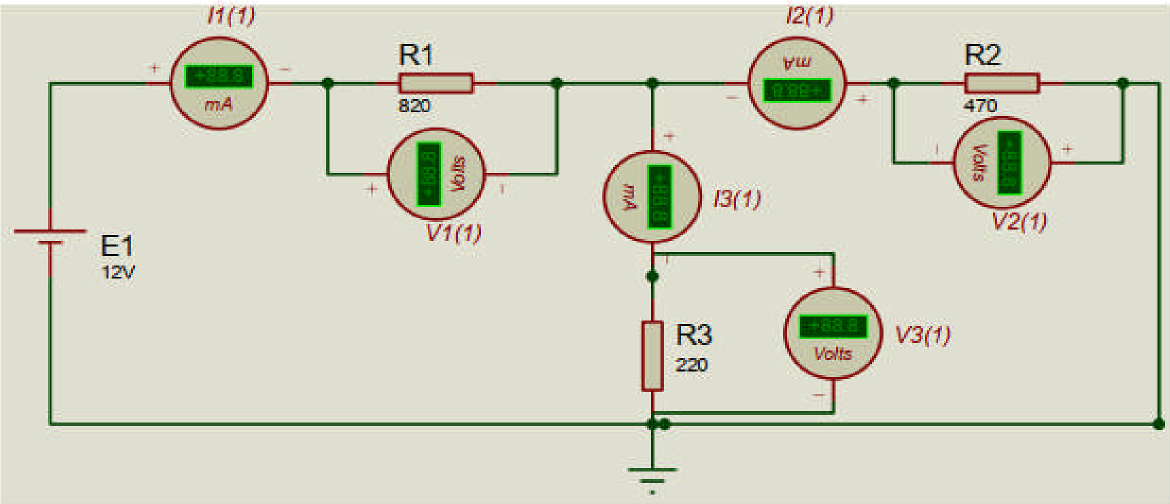


Figure.7

d. Simulate this circuit and complete the table below:

| ***V1(1)* (V)** | ***V2* (1) (V)** | ***V3* (1) (V)** | ***I1* (1)(mA)** | ***I2* (1) (mA)** | ***I3*(1) (mA)** |
|---|---|---|---|---|---|
| | | | | | |

e. Short-circuit the voltage source E1 to obtain the circuit shown below:

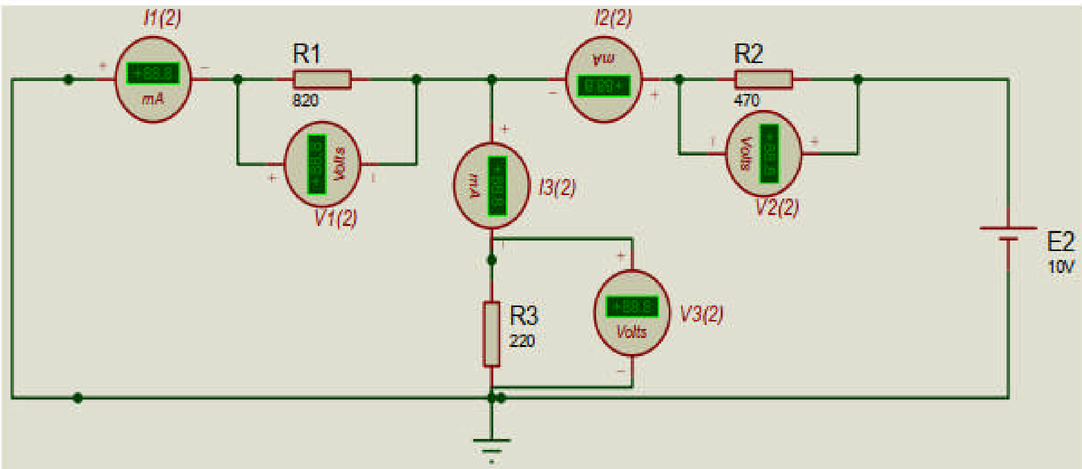


Figure.8

f. Simulate this circuit and complete the table below:

| V1(2) (V) | V2 (2) (V) | V3 (2) (V) | I1 (2)(mA) | I2 (2) (mA) | I3(2) (mA) |
|---|---|---|---|---|---|
| | | | | | |

g. Verify that:

$$Vn = Vn(1) + Vn(2) \qquad 1 \leq n \leq 3$$

And

$$In = In(1) + In(2) \qquad 1 \leq n \leq 3$$

**2. In-Person Activity**

**2.1. Circuit Construction**

**a.** Construct the circuit illustrated below:

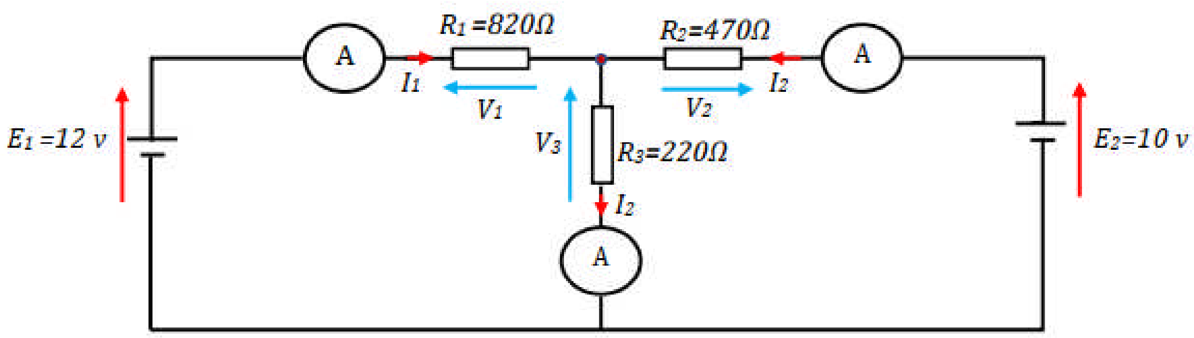


Figure.9

b. Record the various current and voltage measurements in the table below:

| V1 | V2 | V3 | I1 | I2 |
|---|---|---|---|---|
| | | | | |

c. We will now attempt to measure the currents and voltages in the previous circuit using the superposition theorem.

1.**Step 1**: E1 Alone, E2 Deactivated:

- Draw and assemble the circuit.
- Record the various current and voltage measurements in the table below:

| V'1 | V'2 | V'3 | I'1 | I'2 | I'3 |
|---|---|---|---|---|---|
| | | | | | |

2. Step 2: E2 Alone, E1 Deactivated:

- Draw and assemble the circuit.
- Record the various current and voltage measurements in the table below:

| V''1 | V''2 | V''3 | I''1 | I''2 | I''3 |
|---|---|---|---|---|---|
| | | | | | |

**2.2. Tasks to Complete**

a. What equipment is required to set up these circuits?

b. Theoretically calculate the voltages across the resistors R1, R2, and R3 using the superposition theorem.

c. Theoretically calculate the current intensities in all branches using the superposition theorem.

d. Based on the voltage values obtained earlier (both measured practically and calculated theoretically), can we confirm that the superposition theorem holds for these voltages? Why or why not?

e. Based on the current values obtained earlier (both measured practically and calculated theoretically), can we confirm that the superposition theorem holds for these currents? Why or why not?

f. The power dissipated in a resistor is given by the relationship:

$P = I^2 * R = I * V$, Verify whether the superposition theorem is applicable for calculating the power dissipated by a resistor (R1, R2, and R3). In other words, does the relationship P = P' + P'' hold true?

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*Department of Electrical Engineering and Department of Electronics*
****************************************************************************************************************************

*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 Electronics 1* — أعمال تطبيقية في الالكرونيك الأساسية 1

****************************************************************************************************************************

# *PW n°03: Thevenin's Theorem*

Duration: $1^h30$.

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

Report prepared by:

| Last Name | First Name | Group | S/Group | Final Note |
|---|---|---|---|---|
| - | - | - | - | - |
| - | - | - | - | - |
| - | - | - | - | - |
| - | - | - | - | - |

## 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.**
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- **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.**

Person in charge of practical work: Dr ROUABHI.R

# *PW n°03:* Thevenin's Theorem

## I. Objective of the Experiment

The purpose of this lab session is to model complex electrical circuits and simplify them into very basic circuits, allowing us to apply the fundamental laws of electricity without any complex calculations.

## II. Theoretical Background

### 1. Thevenin's Theorem

An active two-terminal network that contains multiple voltage and current sources, as well as several impedances, can be simplified to a single voltage source (Thevenin voltage) in series with a unique impedance (Thevenin impedance). (See Figure 1)

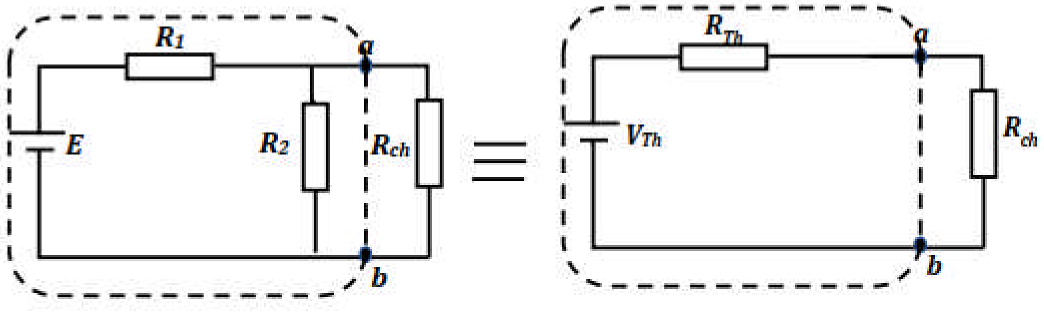


Figure.1: Thevenin Model.

### 1.1. Calculation Procedure

**a. Thevenin Voltage** the resulting current or voltage for the active source.

Disconnect the load resistance (or load impedance $\mathbf{R_{ch}}$ and measure the open-circuit voltage $\mathbf{V_{ab}}$. Therefore: $\mathbf{V_{ab} = V_{th}}$.

**b. Thevenin Resistance this** With the load Rchstill disconnected, short-circuit all voltage sources and disconnect all current sources. Then, calculate the equivalent resistance of the circuit as seen between points **a** and **b** $\mathbf{R_{ab}}$ resulting in the Thevenin resistance:

$$\mathbf{R_{ab} = R_{th}}$$

**Example:**

Consider the following circuit:

To calculate the voltage Vthusing Thevenin's theorem, we need to determine the Thevenin equivalent circuit of the circuit above.

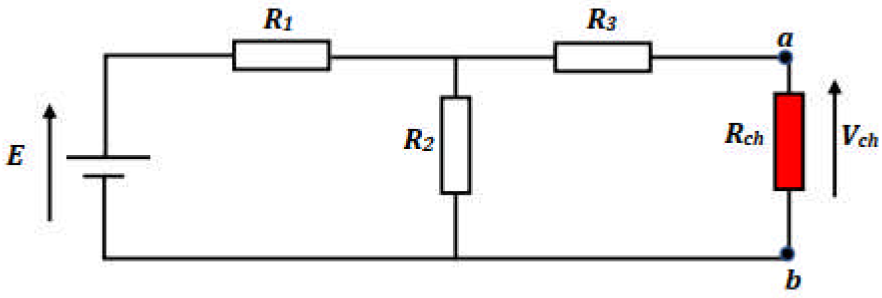


Figure.2.

**a. Calculate $V_{th}$:**

To calculate $\mathbf{V_{th}}$ we must disconnect the load Rchand measure the voltage between points a and b as follows:

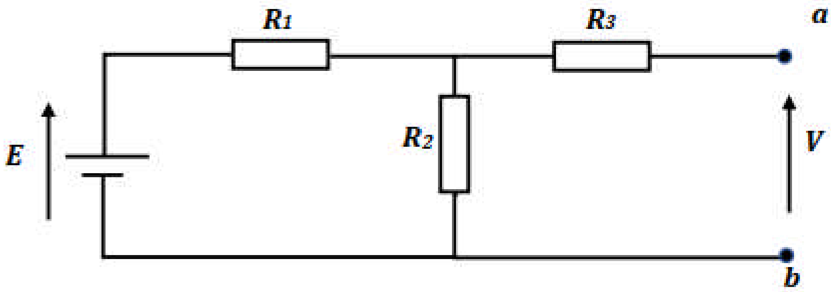


Figure.3.

This circuit is open between points a  and b, so no current flows through the resistance R3 Consequently, the voltage between points a and b will be the same as the voltage across the resistance R2.By applying the voltage divider principle, we find that:

$$V = V_{th} = E\frac{R2}{R2 + R1}$$

**b. Calculate $R_{th}$:**

To calculate $\mathbf{R_{th}}$we must keep $\mathbf{R_{ch}}$ in place while short-circuiting the voltage source E:

The Thevenin resistance $\mathbf{R_{th}}$will correspond to the equivalent resistance of this circuit between points a and b:

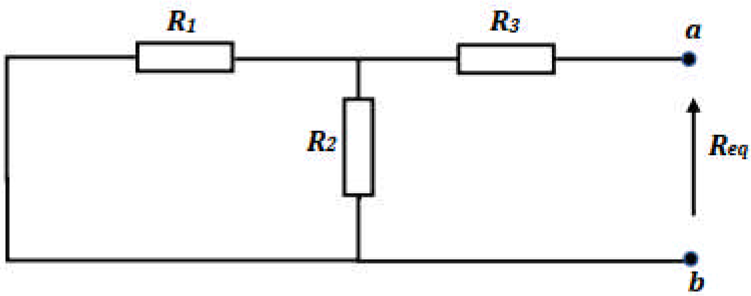


Figure.4.

$$Req = RTh = R3 + (R1 \backslash\backslash R2) = R3 + \frac{R1R2}{R2+R1}$$

Finally, the Thevenin equivalent circuit can be represented as follows:

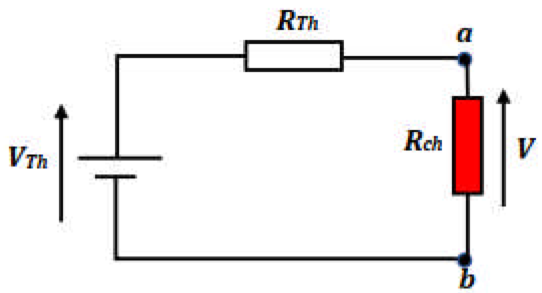


Figure.5.

Therefore, the voltage Vacross the resistance Rch can be expressed as follows: $V = V_{th}\frac{R_{ch}}{R_{ch}+R_{th}}$

### 3. Experimentation

#### 3.1. Personal Work

a. Using Proteus, create the following circuit:

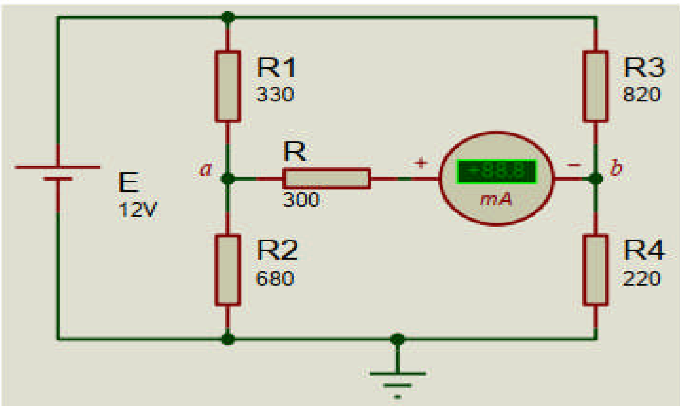


Figure.6.

b. Simulate the circuit and record the current flowing through the resistance R

c. Disconnect the resistance R andmeasure the voltage between points a and b (Vab=$V_{th}$ )as follows:

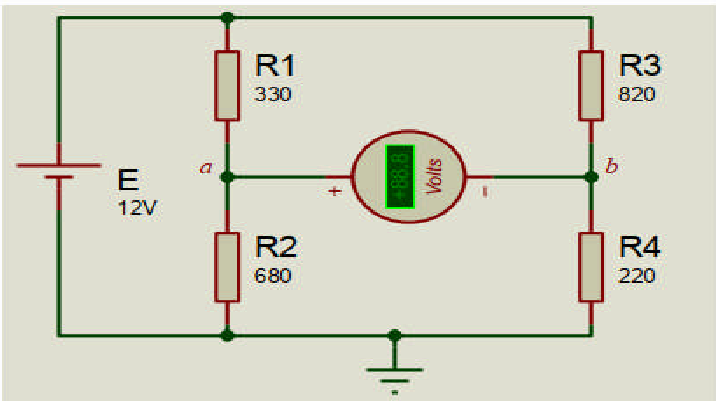


Figure.7.

d. Keep the resistance R disconnected, short-circuit the generator E and calculate the equivalent resistance between points a and b $\mathbf{R_{ab} = R_{th}}$ as follows:

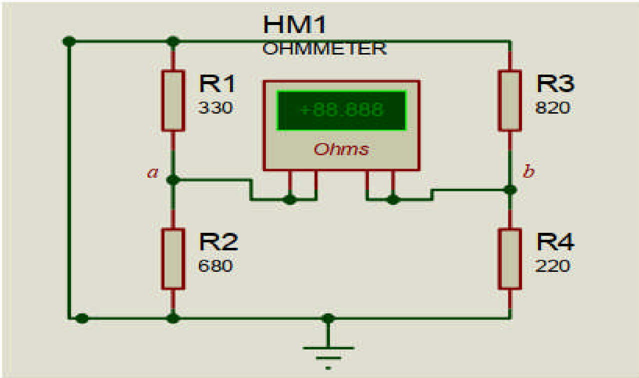


Figure.8.

e. Using the previously obtained measurements $\mathbf{V_{th}}$and $\mathbf{R_{th}}$**,** create the Thevenin circuit and calculate the current flowing through the resistance R as follows:

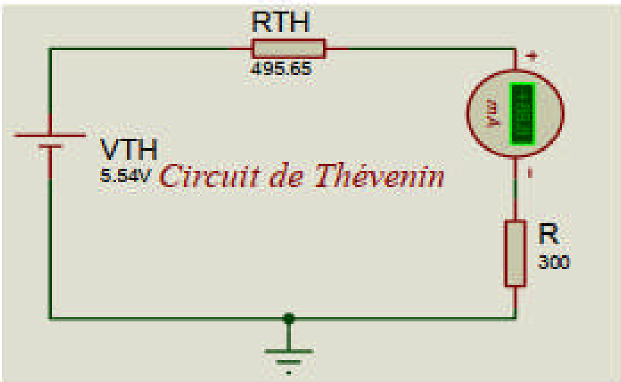


Figure.9.

f. Compare the current found in step e with the current found in step b. What can we conclude about Thevenin's theorem?

### 3.2. In-Person Work

Using the following circuit (Figure 2):

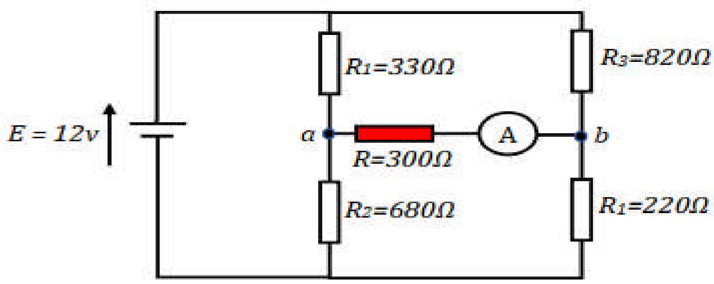


Figure.10.

a. Find the current I  flowing through the resistance R using the mesh analysis method.

b. Determine the Thevenin equivalent circuit ($V_{th}$,$R_{th}$) as seen by the resistance *R*.

c. Deduce the current *I* flowing through *R*

d. Set up the circuit as shown in Figure 2.

e. List the materials used.

f. Measure the current flowing through the resistance *R*.

g. Disconnect the resistance *R* and measure the open-circuit voltage $V_{ab}$ ($V_{ab}= V_{th}$).

h. Short-circuit the voltage source E, keeping the resistance R disconnected. Using an ohmmeter, measure the resistance $R_{th}$ between points **a** and **b** ($R_{ab} = R_{th}$)

i. Draw and construct the Thevenin equivalent circuit using $V_{th}$ and $R_{th}$

j. Measure the current ***I*** flowing through the resistance ***R***.

k. Conclusion.

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*Department of Electrical Engineering and Department of Electronics*
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# *PW n°04: PN junction diode characteristics*

Duration: 1$^{h}$30.

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

Report prepared by:

| **Last Name** | **First Name** | **Group** | **S/Group** | **Final Note** |
|---|---|---|---|---|
| - | - | - | - | - |
| - | - | - | - | - |
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| - | - | - | - | - |

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  - **Last Names and first names of the WP participants.**
  - **Preparation and work in manuscript.**

Person in charge of practical work: Dr ROUABHI.R

***PW n°04:*** **PN junction diode characteristics**

## I. Objective of the Experiment

The main objective of this practical work is to study the influence of forward and reverse bias on the current of a PN junction diode and also to plot the current-voltage characteristic of a PN junction diode. current of a PN junction diode and also to plot the current-voltage characteristic of a diode in the forward and reverse directions.

## II. Theoretical Background

A diode is an active device with two electrodes, usually called an anode and a cathode. A diode consists of a combination of P-type semiconductors (doped silicon or germanium) on the anode side and N-type semiconductors on the cathode side.

Due to the special properties of the semiconductors, current can only flow through the junction in the direction P → N.

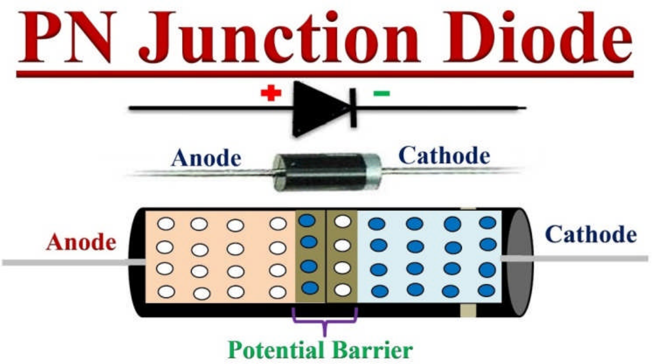


Figure.1: Structure and symbol of a PN junction diode.

### 1. Diode polarisation

The current flowing through the diode follows the exponential law of the voltage applied:

$$I_d = I_s * \left[exp\left(\frac{qV_d}{nKT}\right) - 1\right] = I_s * \left[exp\left(\frac{V_d}{nV_T}\right) - 1\right] \quad (1)$$

With:

***$I_s$***: is called the reverse saturation current. This is the asymptotic value of the current flowing through the junction in reverse polarisation.

***$V_T$***: the thermodynamic voltage $\left(V_T = \frac{KT}{q}\ 26mv\right) at\ \ 25°\mathrm{C}$

q: the charge of the electron (1.6*$10^{-19}$ C).

K: Boltzmann constant (1.3806488*10-23 J/°C).

T: Absolute temperature in Kelvin.

n: Emission coefficient. Depending on the material, it is around 1 for germanium diodes and between 1 and 2 for silicon diodes.

## *PW n°04:* PN junction diode characteristics

The diode can be polarised in two ways:

### 1.1. Polarisation in the direct direction (through direction)

Given a circuit containing a variable voltage source and a resistor with a diode in series in series:

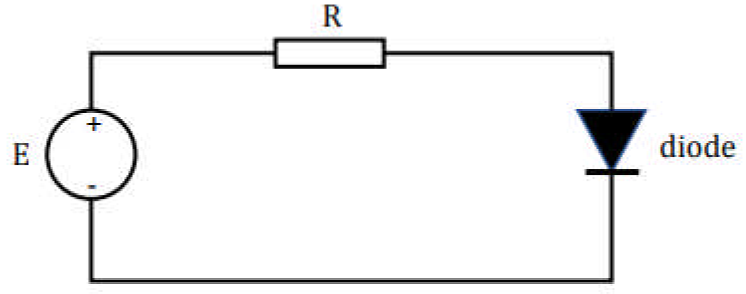


Figure.2: Direct polarisation of the diode.

When the anode is connected to the positive (+) side of the power supply (voltage generator) and the cathode is connected to the negative (-) side, the diode is said to be forward biased (figure 2).

A current flows through the circuit when the voltage across the diode is greater than the threshold voltage $V_0$ ($V_0 = 0.5$ volts for a silicon diode and $V_0 = 0.3$ volts for a germanium diode).

This current increases very rapidly with V and is practically limited by the resistor in series with the diode. In series with the diode. We can see that the current I flowing through the diode is related to the voltage V applied to it by equation (1).

In the case shown in figure 2, the diode is biased in the on direction, so:

$$I_d = I_s * \left[exp\left(\frac{qV_d}{nKT}\right) - 1\right] \qquad (2)$$

### 1.2. Reverse polarisation (blocked direction)

Consider the following circuit:

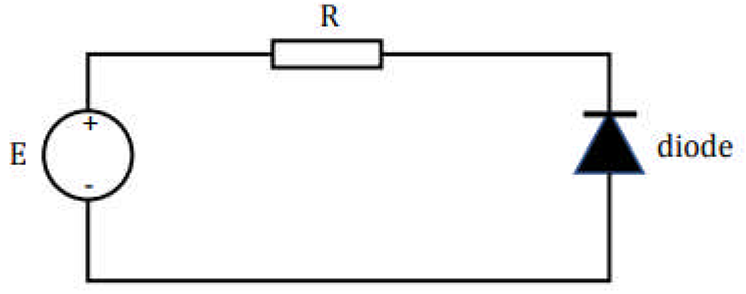


Figure.3: Reverse polarisation (blocked) of the diode.

If the anode is connected to the minus (-) side of the supply and the cathode to the plus (+) side, the diode is said to be reverse biased (Figure 3).

In the case of Figure .3, the diode is reverse biased and $I_d = I_i$; $V_d = V_i$, so equation (1) becomes:

$$I_i = I_s * \left[exp\left(\frac{qV_i}{nKT}\right) - 1\right] \qquad (3)$$

## 2. The current-voltage characteristic $I_d = f(V_d)$

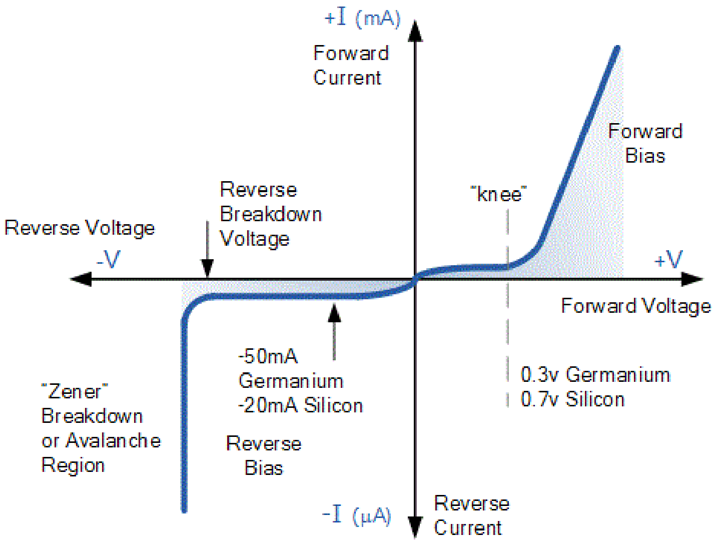


Figure.4: Current-voltage characteristics of the diode.

## III. Experiment Procedure

### 1. Personal work

1.1 Using Proteus, make the following assembl:

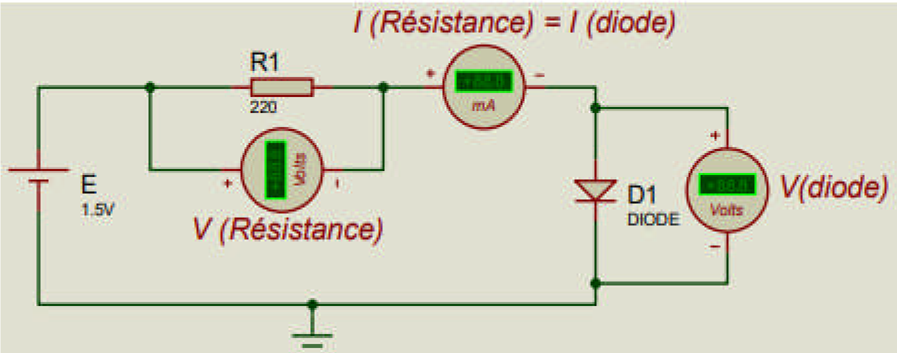


Figure.5

1.2 Simulate the assembly and complete the table below:

Table. 1.

| ***E*** | **0** | **0.3** | **0.5** | **0.7** | **1** | **3** | **5** | **7** | **9** | **11** | **13** | **15** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $V_R$ | | | | | | | | | | | | |
| $V_R$ | | | | | | | | | | | | |
| $I_R$ | | | | | | | | | | | | |
| $V_d$ | | | | | | | | | | | | |
| $I_d$ | | | | | | | | | | | | |

1.3 Invert the diode to obtain the following circuit:

<u>***PW n°04:*** **PN junction diode characteristics**</u>

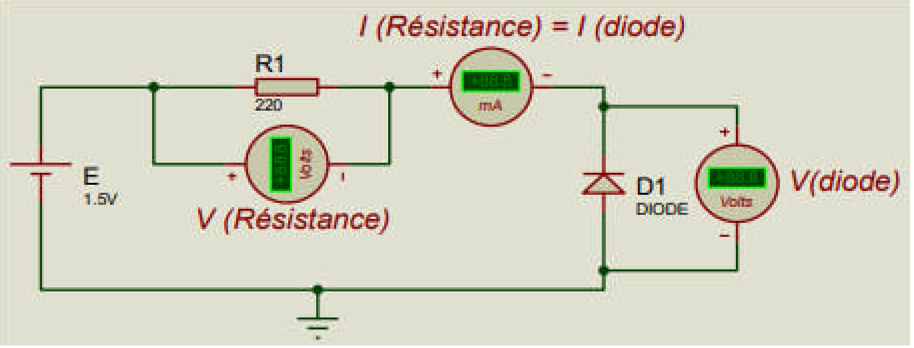


Figure.6

1.4 Simulate the installation and complete the table below:

Table. 2.

| ***E*** | **0** | **0.3** | **0.5** | **0.7** | **1** | **3** | **5** | **7** | **9** | **11** | **13** | **15** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $V_R$ | | | | | | | | | | | | |
| $V_R$ | | | | | | | | | | | | |
| $I_R$ | | | | | | | | | | | | |
| $V_i$ | | | | | | | | | | | | |
| $I_i$ | | | | | | | | | | | | |

1.4 Plot the following functions on the same graph, using appropriate scales: $I_r = f(V_R)$; $I_d = f(V_d)$; $I_i = f(V_i)$.

## 2. Field work

### 2.1. Direct polarisation (through beam)

a. Make the following connection:

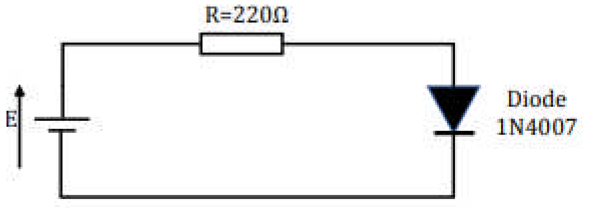


Figure.7

b. By varying the voltage generator *E*, record for each value the voltage drop $V_R$ across the resistor *R* and the current $I_R$ flowing through it and enter these values in the measurement table.

c. By varying the voltage generator *E*, record for each value the voltage drop $V_d$ across the diode and the current $I_d$ flowing through it and enter these values in the measurement table (Table 1).

### 2.2. Reverse polarisation (blocking direction)

a. Make the following circuit:

***PW n°04:*** **PN junction diode characteristics**

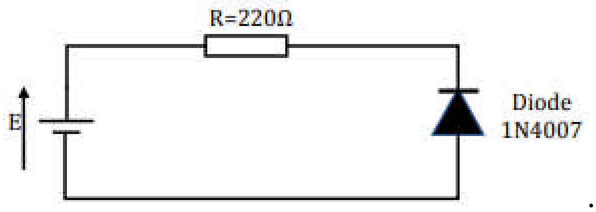


Figure.8

b. By varying the voltage generator $E$, record for each value the voltage drop $V_i$ across the diode and the current $I_i$ flowing through it and enter these values in the measurement table (Table 1).

Table. 3.

| $E$ | 0 | 0.3 | 0.5 | 0.7 | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $V_R$ | | | | | | | | | | | | |
| $V_R$ | | | | | | | | | | | | |
| $I_R$ | | | | | | | | | | | | |
| $V_d$ | | | | | | | | | | | | |
| $I_d$ | | | | | | | | | | | | |
| $V_i$ | | | | | | | | | | | | |
| $I_i$ | | | | | | | | | | | | |

**2.3. Work to be carried out**

a. Identify the equipment used in the experiment.

b. Plot on the same graph, using appropriate scales, the following functions

$Ir = f(V_R); Id = f(V_d); I_i = f(V_i)$.

c. Determine the slope of the line $I_R = f(V_R)$.

d. Determine the threshold voltage of the diode and its dynamic resistance.

e. Find the saturation current $I_s$ of the diode.

f. Conclusion.

# Practical work handout

Subject: **Fundamental Electronics and Electrotechnics 1**

Speciality: Electrotechnics, Electromechanics, Automatic, Renewable energy and environment.

Level: 2nd year bachelor's degree

Author: Riyadh ROUABHI

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***Abstract –***

This practical workbook (PW Fundamental Electronics and Electrotechnics 1) is intended for students in the second year of their bachelor's degree (Electrotechnics, Electromechanics, Renewable Energies and Environment, Automation) at the Mohamed Boudiaf University in M'sila, Algeria. Its aim is to provide them with a working document that will enable them to validate the concepts taught in the lectures and tutorials of Electronics 1 and Electrotechnics 1 and to facilitate their practical application in experimental manipulations. It will also enable them to acquire the necessary know-how to use the equipment and the various measuring instruments used correctly and to gain a good understanding of the methods used. For this reason, the preparation of the practical work must be taken seriously and be the subject of particular attention on the part of the students, in order to obtain the maximum benefit from it without damaging the equipment placed at their disposal. All the sections presented in this document were carried out at the Bidaghogic Electrical Engineering Laboratory of the Mohamed Boudiaf University in M'sila.

***Keywords*** – Single and Three Phases, The hysteresis cycle, The transformer, DC machines, Superposition Theorem, Thevenin's Theorem, PN junction diode characteristics.