People's Democratic Republic of Algeria
الجمهورية الجزائرية الديمقراطية الشعبية
Ministry of Higher Education and Scientific Research
وزارة التعليم العالي و البحث العلمي

Mohamed Boudiaf University - M'sila
Faculty of Technology
ST common trunk

جامعة محمد بوضياف - المسيلة
كلية التكنولوجيا
القاعدة المشتركة

Level: 1st Year Bachelor's Degree
Field: Science and Technology
Stream: Renewable Energy
Option: Renewable Energies and the Environment

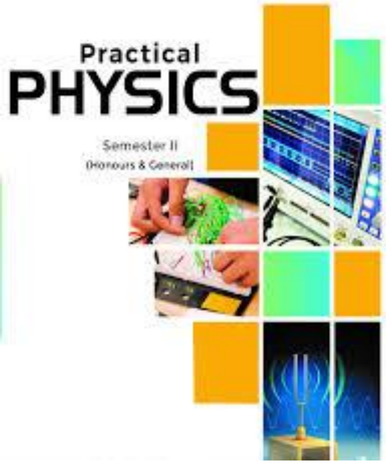
Pedagogical Support

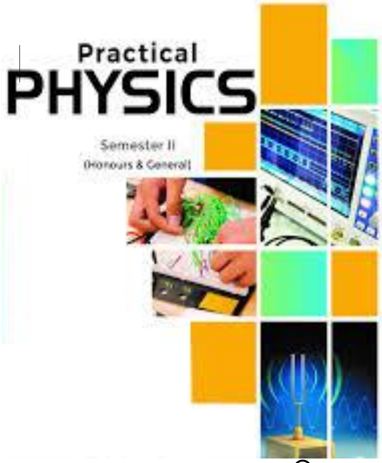
Course titled:

Physics Practicals 2

Prepared by:

Badis BAKRI
Associate professor Class A





Academic Year: **2025-2026**

رقم: 127/ ن.ع.ب.ع /ك.ت /2026

المسيلة في: 28 أفريل 2026

شهادة ادارية

المصادقة على تقارير خبرة للموافقة على مطبوعة بيداغوجية

بعد الإطلاع على تقارير لجنة الخبراء للموافقة على المطبوعة البيداغوجية للأستاذة : : **بكري باديس – أستاذ محاضر قسم أ**، بالقاعدة المشتركة بكلية التكنولوجيا بجامعة محمد بوضياف بالمسيلة والتي كانت كلها ايجابية ، تمّ تقرير التّالي:

1-المصادقة على تقارير لجنة الخبراء للموافقة المطبوعة البيداغوجية والمعنونة بــ:

Physics Practicals 2
Common Base Renewable Energies– Cycle License

2- حيث تمّ تشكيل هذه اللجنة بناء على اجتماع المجلس العلمي للكلية المنعقد بتاريخ **2026/02/17** المكونة من السّادة الآتية أسماؤهم:

- **بن قسمية هاني**، أستاذ ، جامعة محمد بوضياف- المسيلة
- **بورزق يوسف إسلام**، أستاذ محاضر "أ"، جامعة محمد بوضياف- المسيلة
- **بشة حبيبة**، أستاذ محاضر "أ"، جامعة محمد خيضر- بسكرة

وتمت الموافقة بالاجماع على هذه المطبوعة.

رئيس المجلس العلمي للكلية

جامعة محمد بوضياف المسيلة
المجلس العلمي

د. علي جريوي

Semestre: 2
Unité d'enseignement: UEM 1.2
Matière 1: TP Physique 2
VHS: 45h00 (TP: 1h30)
Crédits: 2
Coefficient: 1

Objectifs de l'enseignement
Consolider à travers des séances de Travaux Pratiques les notions théoriques abordées dans le cours de Physique 2.

Connaissances préalables recommandées
Mathématiques 1, Physique 1.

Contenu de la matière:

5 manipulations au minimum (3h00 / 15 jours)

- Présentation des instruments et outils de mesure (Voltmètre, Ampèremètre, Rhéostat, Oscilloscopes, Générateur, etc.).
- Les lois de Kirchhoff (loi des mailles, loi des nœuds).
- Théorème de Thévenin.
- Association et Mesure des inductances et capacités
- Charge et décharge d'un condensateur
- Oscilloscope
- TP sur le magnétisme

Mode d'évaluation:
Contrôle continu: 100%

Foreword

Foreword

Intended for first-year Renewable Energies and Environment students (LMD system in Science and Technology), this Pedagogical Support document for Physics Practicals 2 provides a practical working resource. Its goal is to aid in the comprehension of course theory and to streamline its practical implementation during experimental laboratory work.

In the LMD system, experimental activities, and therefore measurements, hold an important place. These practicals aim to complement the concepts covered in the first-year physics lectures and tutorials. It is also essential not only to acquire the know-how necessary for the proper use of equipment and the various measuring instruments employed, but also to achieve a good understanding of the methods implemented. This is why the preparation for practical work must be considered seriously and carefully by students, in order to derive maximum benefit from it without damaging the equipment made available to them.

This document consists of six parts that prepare students for:

- Presentation of measuring instruments and tools (Voltmeter, Ammeter, Rheostats, Oscilloscopes, Generator, etc.),
- Kirchhoff's Laws (Mesh Law, Node Law),
- Thévenin's Theorem,
- Association and measurement of inductances and capacitances,
- Charge and discharge of a capacitor,
- Oscilloscope,
- Practical on Magnetism,

Workload

22h30, Practicals: 1h 30min per week.

Assessment Method

Continuous 100%

Pre-requisites

Scientific high school mathematics and physics tools.

Target Audience

First-year ST students at the University of M'sila,

Faculty: Technology.

Contact: via the Moodle platform, any question related to the practicals must be posted on the dedicated forum so that everyone can benefit from my response. I commit to answering questions posted within 48 hours. The link:

https: https://moodle.univ-msila.dz/moodle/course/view.php?id=3587
By email, I commit to responding within 48 hours of receiving the message, barring unforeseen circumstances, at badis.bakri@univ-msila.dz

Recommendations during practical sessions

Experiments will be conducted in pairs or groups of three, according to the rotation cycle defined at the beginning of the semester.

Student attendance is mandatory and will be checked. Any unjustified absence or failure to submit a report will result in a grade of 0/20, which will be taken into account in the average calculation.

In case of absence, a copy of the justification must be given to the teacher at the beginning of the next session; the original must be submitted to the office of the concerned department.

It is strictly forbidden to move equipment from one station to another. In case of breakdown or faulty equipment, contact the teacher.

Teaching Objectives

To consolidate, through practical sessions, the theoretical concepts covered in the Physics 2 course.

Recommended Prior Knowledge

Mathematics 1, Physics 1.

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Practical Work: 01
Presentation of Measuring Instruments and Tools

1. Theoretical Reminder

A precise understanding of physical and electrical phenomena is linked to the concept of measurement, as the simple observation of such a phenomenon cannot give us a broad idea. Therefore, to achieve a better understanding of a phenomenon, one must resort to experiments carried out using measuring instruments.

This measuring instrument allows for establishing a correspondence between the mathematical tool and the state of a phenomenon.

The measurement diagram is as follows:

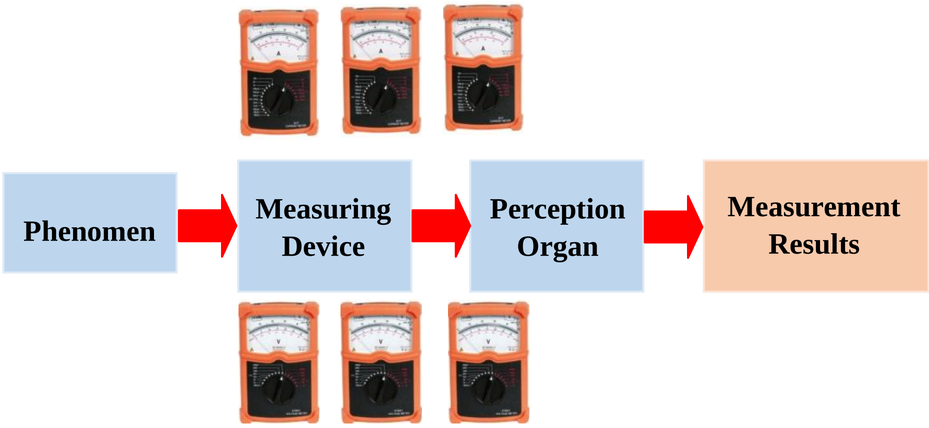


Figure 1. Measurement diagram.

2. Quantity (Measurable)

A quantity is said to be measurable if a numerical value can be assigned to it based on observations.

Furthermore, the sum and/or product of measurable quantities has a meaning.

Among measurable quantities, one can cite length, absolute temperature, resistance, etc.

It is a characteristic of a phenomenon, body, or substance that can be distinguished qualitatively (distance, angle, etc.) by a name and determined quantitatively by a value (a number expressed in the chosen unit).

The main electrical quantities that an electronics engineer may need to measure are the following:

- Voltage, or potential difference between two points;
- Current intensity in a branch,
- Resistance of a receiver,
- Capacitance of a capacitor,
- Power dissipated in a circuit,
- Frequency and period of a signal.

The base quantities and units in the International System are given by the following table:

Table 1. Base Quantities and Units of Measurement.

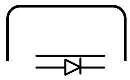
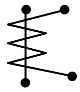
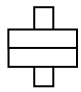
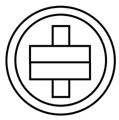
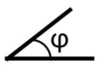
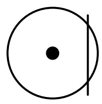
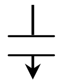
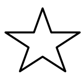
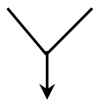
Size	Symbol	Unit	Symbol	Measuring device
Voltage	U	Volt	V	 Voltmeter
Intensity	I	Amps	A	 Ammeter
Puissance	P	Watts	W	 Wattmeter
Resistance	R	Ohms	Ω	 Ohmmeter
Capacitance	C	Farad	F	 Capacitance meter
Inductance	L	Henry	H	 Henry meter
Period	T	Second	s	 Period Meter
Frequency	F	Hertz	Hz	  Frequency Meter

3. Graphical Symbols of Measuring Instruments

Electrical symbols are used to represent or explain the real elements of an electrical installation.

On the dial of an analog measuring instrument, the manufacturer often indicates the type of instrument, the nature of the current, the insulation voltage, the reading position, the accuracy class, the sensitivity, ….etc.

Table 2. Symbols Found on the Dials of Analog Measuring Instruments.

Symbol	Meaning	Symbole	Meaning
	Direct Current		Moving Magnet Instrument
	Alternating Current		Moving Magnet with Rectifier
	Direct and Alternating Current		Moving Iron Instrument
	Vertical Reading Position		Electrodynamic Instrument
	Horizontal Reading Position		Ferrodynamic Instrument
	Inclined Reading Position		Induction Instrument
ex : 50Hz…100KHz	Frequency Band		Electrostatic Instrument
	Insulation Voltage: 500V		Thermal Instrument
	Insulation Voltage: 1kV	0.5 or 1 or 2	Instrument Accuracy Class: 0.5% or 1% or 2% of full scale

4. The Objective of this Practical Work

The objective of this practical work is to know how to use the laboratory equipment (multimeter, Function Generator, Oscilloscope, etc....)

5. Procedure

5.1. Use of Measuring Instruments

5.1. 1. Multimeter

A multimeter (sometimes called a universal tester) is a set of electrical measuring instruments grouped into a single housing11, generally consisting of a voltmeter, an ammeter, and an ohmmeter. The voltmeter and ammeter functions are available for both direct and alternating current.

Figure 2. Digital Multimeter.

5.1.2. Multimeter Operation as a Voltmeter

Turn the selector to the "volt" side of the multimeter. Start with the highest range. Then use the second lead to connect the COM terminal to the other pole of the device across which the measurement is being made. Then turn on the circuit and observe the displayed value.

The unit of voltage in the International System is the volt (V), also using kV or kilovolt, 1 kV = 1000 V, and mV, 1 mV = 0.001 V.

Multimeter Preparation:

The main objectives of this part are to know how to measure voltage, characterize the voltage existing between two points, and select the appropriate range.

- Select DC, AC,
- "COM" terminal and "V" terminal,
- Identify the ranges (20mV, and 2, 20, 200, 600 V) and place the selector on the highest range (600),

- Setting up the multimeter, open circuit. A voltmeter is always connected in parallel in a circuit. Without modifying the main circuit, connect the multimeter in parallel across the terminals of the dipole whose voltage is to be measured. The current enters through the V terminal and exits through the COM terminal. The multimeter indicates "0",
- Set up the circuit in figure 3 and connect the voltmeter.

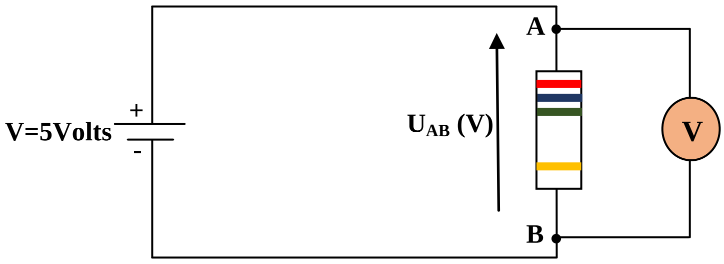


Figure 3. Voltmeter Connected in Parallel Across a Resistor.

- Place the multimeter as indicated in the diagram.
- Set the multimeter to the "voltmeter" function to measure DC voltage and place the selector on the "20" range, for example.
- Turn on the multimeter, then measure and note the value of the voltage UAB.
- Copy the following table and complete it.

Voltmeter Range	20 mV	2 V	10 V	20 V	200 V	600 V
U_{AB} (V)	…….	…….	…….	…….	…….	…….

- If we set the voltmeter to the "600 V" range, we can measure voltages between 0 V and 10V, explain why the voltmeter does not display the value of the U_{AB} voltage on the first two ranges?

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- Which is the most precise range? Why?

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- Set to the best range and reverse the voltmeter leads. What voltage is measured here? What is the relationship between U_{AB} and the measured voltage?

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5.1.3. Multimeter Operation as an Ammeter

Turn the selector to the "ampere" side of the multimeter. Start with the highest range. Then use the second lead to connect the COM terminal to the circuit and thus towards the negative pole of the generator. Then turn on the circuit and observe the displayed value.

The unit of current in the International System is the ampere (A), also using mA or µA, 1 A = 1000 mA = 1,000,000 µA.

Multimeter Preparation:

The main objectives of this part are to know how to measure the current or current intensity flowing in the circuit and to select the appropriate range.

- Select DC, AC;
- "COM" terminal and "A" terminal;
- Identify the ranges (1, 3, 100, 300 mA, and 1, 5, 10 A) and place the selector on the highest range.
- Setting up the multimeter, open circuit. An ammeter is always connected in series in a circuit. It measures the intensity of a current passing through it.
- Set up the circuit in figure 4 with the ammeter connection,

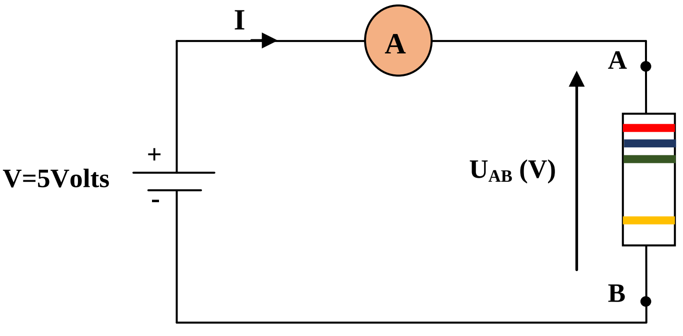

Figure 4. Ammeter Connected in Series with a Resistor.

- Place the multimeter as indicated in the diagram,

- Set the multimeter to the "ammeter" function to measure DC current and place the selector on the "300 mA" range, for example,
- Open the circuit,
- Identify the direction of the current leaving the + terminal of the generator,
- Connect the ammeter between two dipoles in the circuit, so that the current enters the ammeter through the "300 mA" terminal and exits through the "COM" terminal,
- Close the circuit,
- Turn on the multimeter, then measure and note the value of the current I,
- Copy the following table and complete it.

Ammeter Range	1 mA	3 mA	100 mA	300 mA	5 A	10 A
I (A)	…….	…….	…….	…….	…….	…….

- Why does the ammeter not display a value for the intensity on the first three ranges?

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- Which is the most precise range? Why?

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- Set to the best range and reverse the ammeter leads. Why is the measured intensity negative?

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5.1.4. Multimeter Operation as an Ohmmeter

Unlike the voltmeter and ammeter, the ohmmeter is an active device: it has an internal battery, of known value, and sends current into the circuit, which it measures. To measure the value of a resistor, the two probes of the ohmmeter must be connected to the ends of this resistor while it is not receiving current from the rest of the circuit. Indeed, otherwise, this current would add to the current supplied by the ohmmeter, which would distort the measurement.

Turn the selector to the "ohmmeter" side of the multimeter. Start with the highest range. Then use the second lead to connect the COM terminal to the other pole of the device across which the measurement is being made, in our case the resistor. Then turn on the circuit and observe the displayed value.

The unit of resistance in the International System is the ohm (Ω), also using kΩ, 1 kΩ = 1000 Ω.

Multimeter Preparation:

The main objectives of this part are to know how to measure a resistance and to select the appropriate range.

- "COM" terminal and "Ω" terminal;
- Identify the ranges (200Ω, 20kΩ, 200kΩ, 200MΩ, 200MΩ) and place the selector on the smallest range,
- Setting up the multimeter, open circuit. An ohmmeter is always connected in parallel across a resistor,
- Set up the circuit in figure 5 and connect the ohmmeter,

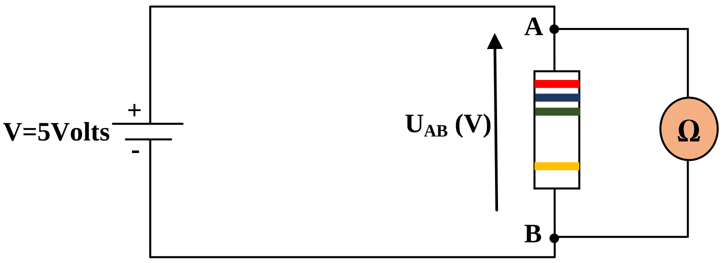

Figure.5. Ohmmeter Connected in Parallel Across a Resistor.

- Place the multimeter as indicated in the diagram,
- Set the multimeter to the "ohmmeter" function to measure a resistance and place the selector on the small range,
- Turn on the multimeter, then measure and note the value of the resistance R,
- If the value "1" is displayed, the range value must be increased,
- Copy the following table and complete it.

			
Ohmmeter Range	....	....	....
R(Ω)	....	....	....

- If we set the ohmmeter to the "20kΩ" range, we can measure resistances between 0 Ω and 20kΩ, explain why the ohmmeter does not display the value of resistance R on the first range?

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- Which is the most precise range? Why?

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5.2. Using the function generator and the oscilloscope

5.2.1. The oscilloscope

An oscilloscope is a measuring instrument intended to visualize an electrical signal, most often variable over time. It allows observing temporal variations, either of electrical voltages, or of various other physical quantities previously transformed into voltage by means of suitable converters or sensors. The output curve of an oscilloscope is called an oscillogram.

It is a device that allows visualizing signals (not measuring them!).

It always consists of four blocks:

- The horizontal sweep system,
- The vertical sweep system,
- The choice of functions for visualization,
- The synchronization system (in English: trigger).

5.2.2. Function Generator (FG)

The function generator (FG) is a versatile measuring instrument essential in your workshop or laboratory. This element allows generating a multitude of waves with precision and fluctuating their amplitude at will. Frequency sweep is available on some models via voltage-controlled frequency.

This device delivers various types of periodic signals in a frequency range known as "low frequency".

Using the manufacturer's manual provided, or by connecting the FG directly to the oscilloscope.

Different types of waves can be selected depending on the type of generator (FG). Three types of waves exist: sinusoidal, triangular (sawtooth), and rectangular.

- Set up the circuit in figure 6 and connect the ohmmeter,

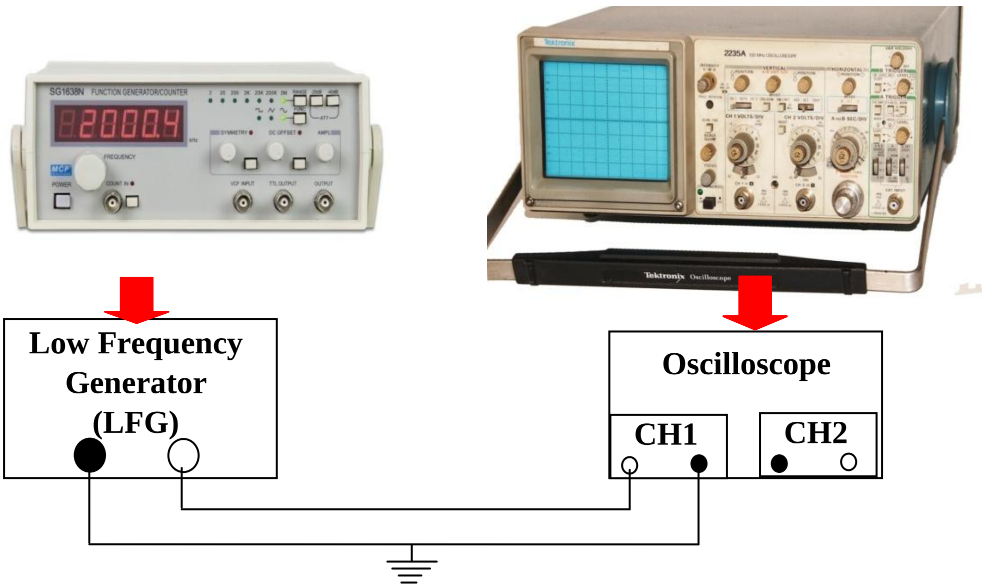
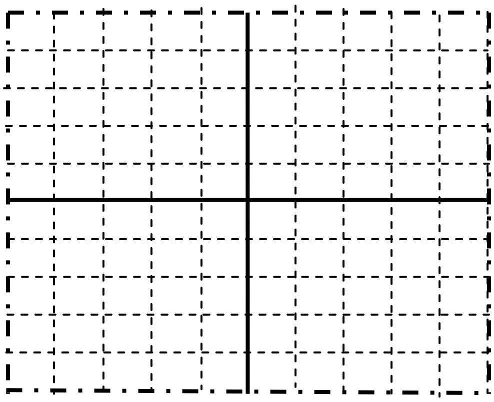


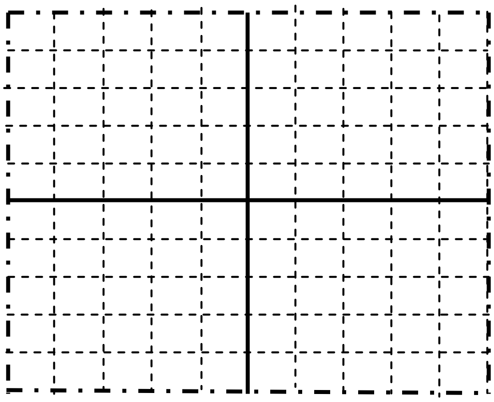
Figure 6. Function generator assembly with the oscilloscope.

From the FG, choose a sinusoidal signal, then fill in the following table:

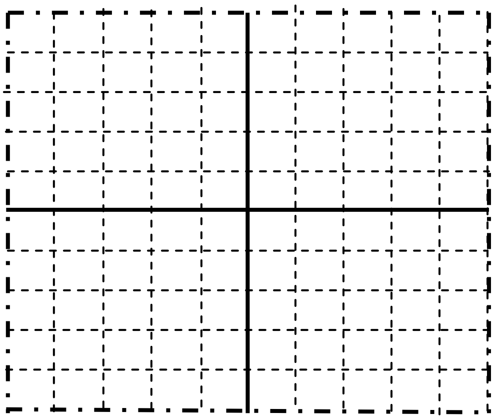
- From the FG, choose a sinusoidal, triangular (sawtooth), and rectangular signal.
- Draw the obtained signal, with the oscilloscope in the AC position.



Signal sinusoïdal



Signal triangulaire (dent de scie)



Signal rectangulaire

Figure 7. AC Output Voltage Using the Oscilloscope.

- In your opinion, what are the different types of signals that the FG can deliver ?

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- Frequency Range: What are the maximum and minimum frequencies that the FG can deliver?

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6. Conclusion

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Practical Work: 02

Kirchhoff's Laws

1. Theoretical Recall

Kirchhoff's laws are statements used to predict how electric current intensity and potential difference behave in an electrical circuit.

There are two laws:

Kirchhoff's Laws

- **Node Law (or Kirchhoff's Fi rst Law)**
- **Mesh Law (or Kirchhoff's Se cond Law)**

2. Some Definitions

- **Dipole:** An electrical or electronic component with two terminals (examples: resistor, capacitor, ...);
- **Network:** A set of dipoles connected in any manner,
- **Node:** A point where at least 3 dipoles meet,
- **Branch:** A set of dipoles in series placed between two nodes,
- **Mesh:** A closed loop made up of at least 2 branches.

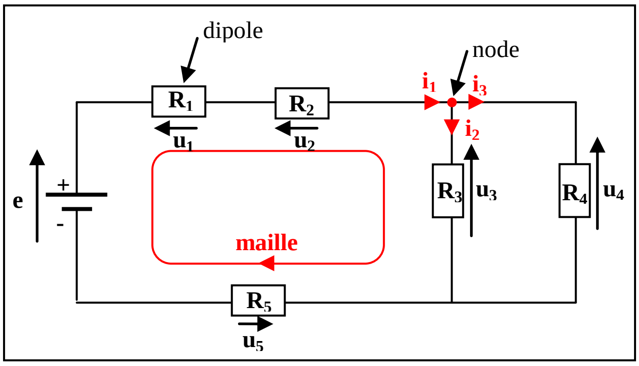


Figure 1. Electrical circuit.

2.1. Node Law

A node is a connection linking at least three dipoles. The represented circuit contains two nodes.

The node law states that:

- The sum of the intensities of the currents arriving at a node equals the sum of the intensities leaving the node.

Or:

- The algebraic sum of the currents arriving and leaving a node is zero (no accumulation of electricity).

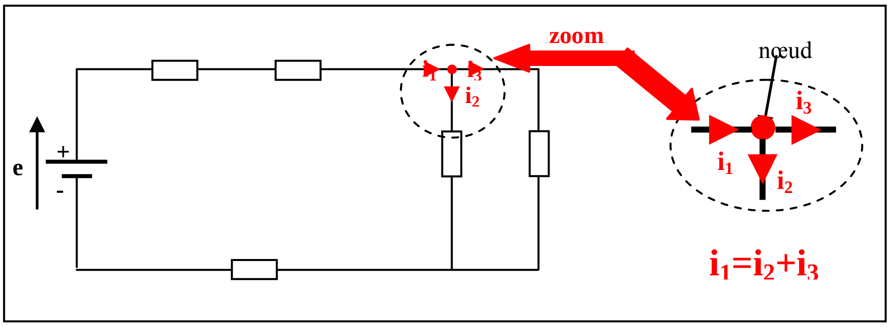


Figure 2. Electrical circuit (Node law).

2.2. Mesh Law

- The sum of the voltages (with an algebraic +/- sign) around a mesh is zero.

$$\sum \pm u_k = 0$$

Application Rules

- An arbitrary direction of traversal for the mesh is fixed,

A + sign is placed before voltages whose arrows follow the direction of traversal, and a - sign if the arrows are in the opposite direction.

Example : $e - u_1 - u_2 - u_3 - u_5 = 0$

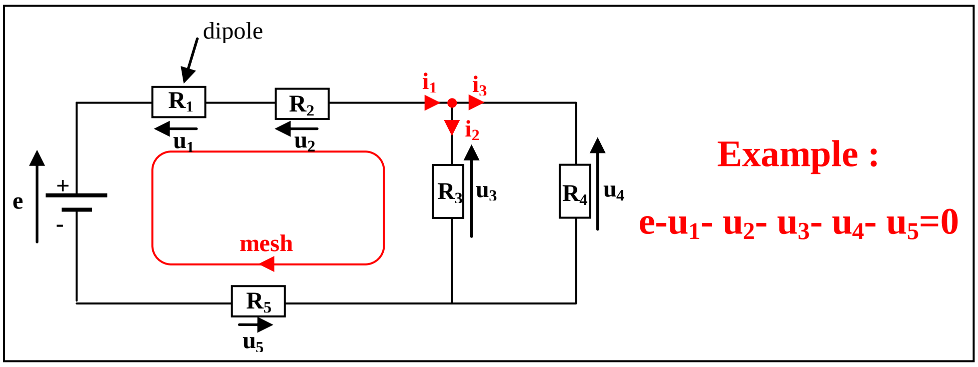


Figure 3. Electrical circuit.(Mesh law).

- Taking the same circuit as in figure 3,

$$\sum \pm u_k = \sum \pm R_k \; i_k$$

Application Rules

- An arbitrary direction of rotation of the mesh is fixed,
- A + sign is placed before the voltages u_k whose arrows follow the direction of traversal, and a - sign if the arrows are in the opposite direction.
- A + sign is placed before $R_k{*}i_k$ when the direction of the current coincides with the arbitrary direction of traversal of the mesh and a - sign in the opposite case.

Application example for figure 4

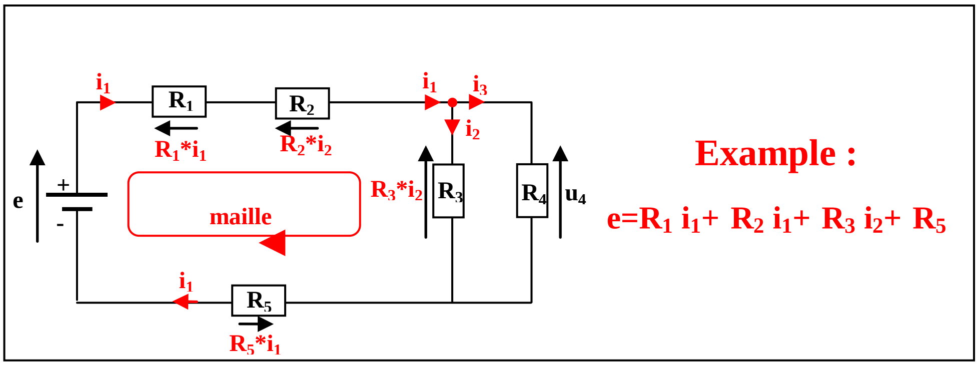


Figure 4. Electrical circuit.(Mesh law).

3. Objective of this Practical Work

The objective is to define a set of methods allowing the study of an electrical circuit traversed by direct currents.

The node law and the mesh law are simple to understand and are part of the fundamental concepts to know in electronics, just like Ohm's law.

4. Purpose of the Experiment

- Perform measurements of current, voltage, and resistance using a multimeter.
- Determine the equivalent resistance of a mixed circuit. Verify the node law and the mesh law.
- Calculate the resistance using Ohm's law. Assemble the setup of simple and mixed electrical circuits.
- Highlight the usefulness and use of the Wheatstone bridge and know metals based on the measurement of resistivity.

5. Concepts and Preparation Work

5.1. Some Laws of Electrical Circuits

Consider a circuit consisting of a generator (E (V)) connected to a resistance R (Ω) (expressed in ohms) using conducting wires (figure 5).

Voltage is responsible for the movement of charges in an electrical circuit, current is the flow of these charges, and the resistance of a circuit element opposes the passage of current.

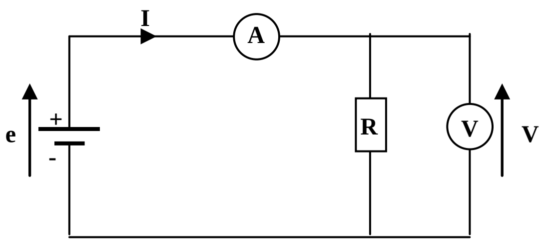


Figure 4. Simple Resistive Load Circuit.

Voltage V (expressed in Volts) is measured using a voltmeter (V). This is a measurement performed in parallel with a circuit element.

Current I (expressed in Amperes) is measured using an ammeter (A). This is a measurement performed in series with a circuit element. According to Ohm's law, measurements taken across a resistance must satisfy the relation:

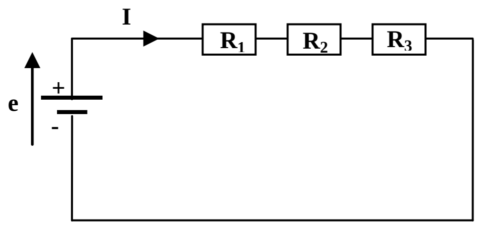
$V=R.I$

A group of resistances ($R_1,R_2,\dots,R_n$) in series has an equivalent resistance given by $R_{eq}=R_1+R_2+\dots\dots+R_n$, whereas $1/R_{eq}=1/R_1+1/R_2+\dots\dots+1/R_n$ when these resistances are connected in parallel.

<u>Calculate:</u>

The equivalent resistance for R_1=100Ω, R_2=150Ω, R_3=200Ω, for the following cases:

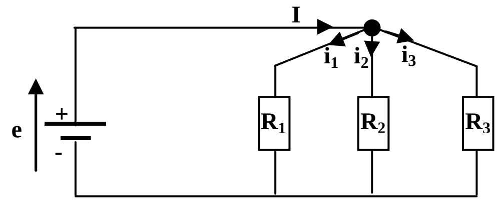
- R_1,R_2,R_3 are connected in series R_{eq}=……Ω.



R_{eq}=…………………..Ω

Figure 5. Simple circuit (three resistors connected in series).

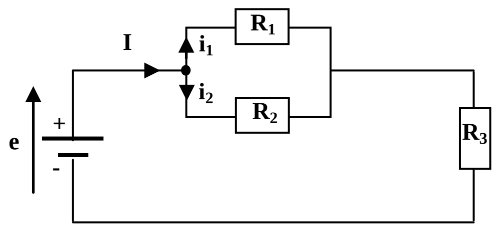
- R_1,R_2,R_3 are connected in parallel R_{eq}=……..Ω.



R_{eq}=…………………..Ω

Figure 6. Simple circuit (three resistors connected in parallel).

- R_1,R_2,R_3 are connected in a mixed circuit (($R_1//R_2$)R_3 in series).



R_{eq}=…………………..Ω

Figure 7. Simple circuit (three resistors connected in a mixed configuration).

- R_1 R_2 R_3 are mounted in a mixed circuit (R_1//(R_2+R_3)) in series).

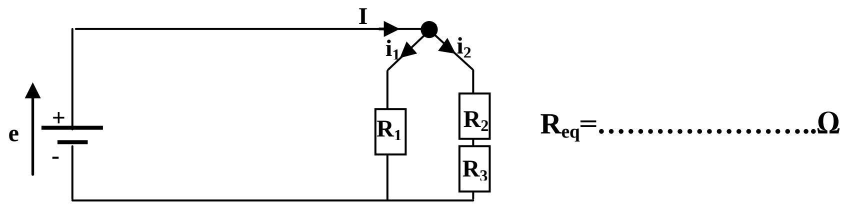
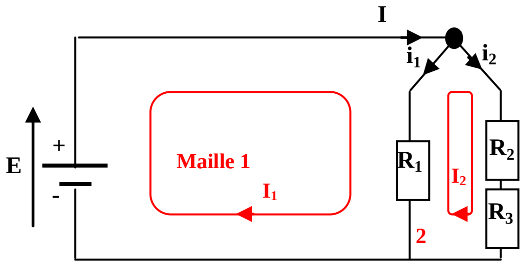


Figure 8. imple circuit (three resistors connected in a mixed configuration) (R_1//(R_2+R_3)).

Note: The equivalent resistance is calculated from the equivalent circuit where each branch is replaced by a resistance, first simplifying the series resistor groupings.

- The node law applies to the branching points of circuit elements. The node law states that the sum of currents entering a node equals the sum of currents leaving the node.
- The mesh law applies to loops in the electrical circuit. The mesh law states that the sum of voltage rises when traversing a loop equals the sum of voltage drops.

Application Example



- Mesh N°.1 traversed by the imaginary current I_1: $E=(i_1-i_2)\,R_1$

Mesh N°.2 traversed by the imaginary current I_2: $0=(i_2-i_1)\,R_1+(i_2)\,(R_1+R_2)$

Where **E** is the voltage across the generator.

5.2. Wheatstone Bridge

The Wheatstone bridge is used to convert a variation in resistance into a variation in voltage, making it a sensor in environments where measurement is difficult.

Consider the setup in figure. 9.

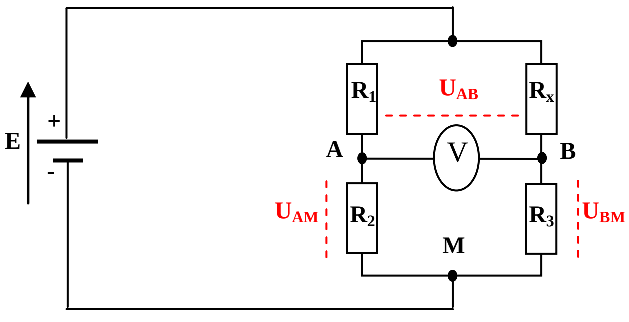


Figure 9. Wheatstone Bridge.

- Indicate the direction of U_{AM}; U_{BM}; U_{AB} on figure 9.
- Express $U_{BM}=f(R_3,R_x,E)$

U_{AM} =…………………………………………………

- Deduce $U_{AB}=f(R_1,R_2,R_3,R_x,E)$

U_{AB}=………………………………………………………

- If U_{AB}=0, the bridge is said to be balanced.

Show that the expression for R_x takes a form independent of the supply voltage.

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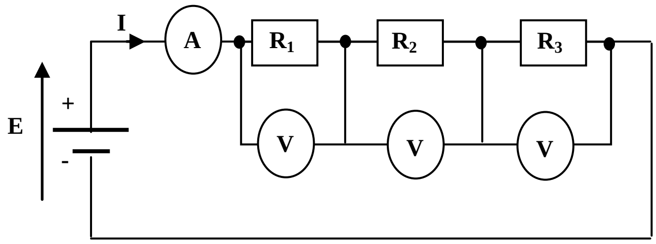
6. Practical Part

6.1. Simple Circuits

6.1.1. Resistors in Series

- Assemble the circuit where R_1,R_2,R_3 are connected in series.

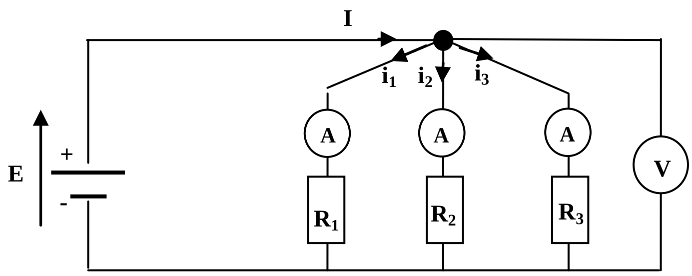


- Power your circuit with a voltage E=4.5V.
- Complete the adjacent table.

	R_1	R_2	R_3
I(mA)			
V(Volts)			
Resistance (Ω)			

6.1.2. Resistors in Parallel

- Assemble the circuit where R_1, R_2, R_3 are connected in parallel.



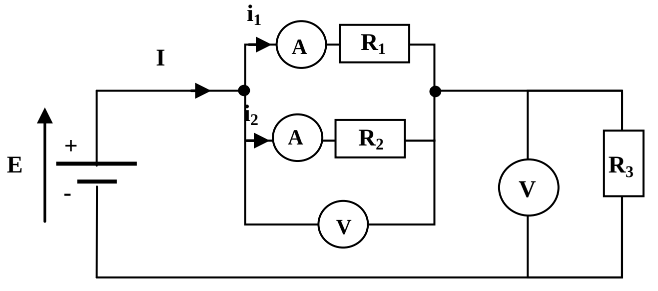
- Power your circuit with a voltage E=4.5V,

- Complete the adjacent table.

	R_1	R_2	R_3
I(mA)			
V(Volts)			
Resistance (Ω)			

6.1.3. Mixed Circuits

- Assemble the circuit where R_1,R_2,R_3 are connected as follows:

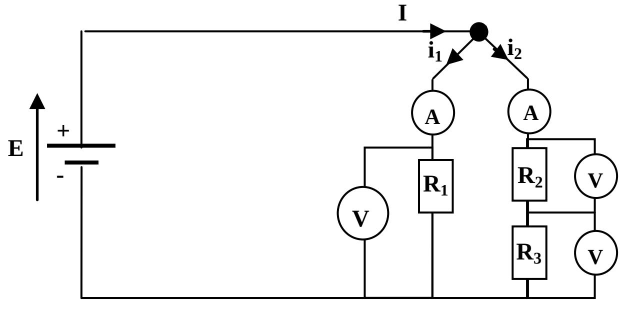


- Power your circuit with a voltage E=4.5V,
- Complete the adjacent table.

	R_1	R_2	R_3
I(mA)			
V(Volts)			
Resistance (Ω)			

- Assemble the circuit where R_1,R_2,R_3

are connected as follows:



- Power your circuit with a voltage E=4.5V,
- Complete the adjacent table.

	R_1	R_2	R_3
I(mA)			
V(Volts)			
Resistance (Ω)			

7. Measurement of the Resistivity of a Material

Assemble the setup of figure 9 (Wheatstone Bridge), where R_1=1kΩ, R_2=100kΩ, and the resistive wire in place of R_x,

- Power your circuit with a voltage E=4.5V,
- Vary the resistance R_3 until the bridge is balanced (the galvanometer indicates zero voltage).
- For different values of the cross-section S of the resistive wire of length l=1m.

a) Complete the adjacent table

Wire Diameter (mm)	*0,5*	*0,7*	*1*
R_3 (Ω)			
Resistance ***R_x (Ω)***			
Resistivity ***$\rho = R_x .S/l$ (Ω .cm)***			

b) Deduce the type of the two metals; use the displayed table of resistivity values.

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7. Conclusion

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جدول يمثل قيم المقاومة النوعية لبعض المعادن

Table representing resistivity values of some metals

Electrical Resistivity at T=20°C

Material	Resistivity (Ω .cm)	Temperature Coefficient (K^{-1})
Silver	1.63	0.0041
Copper	1.69	0.00430
Gold	2.2	0.0040
Aluminium	2.67	0.0045
Tungsten	5.4	0.0048
Zinc	5.96	0.0042
Brass (Copper+Zinc Alloy)	6.2-7.8	0.0016-0.0017
Iron	10.1	0.0065
Platinum	10.58	0.00392
Lead	20.6	0.0042
Constantan (Cu55/Ni45 Alloy)	52	+/-0.0002
Carbon	1375	$-0.2\ 10^{-3}$
Germanium	$46\ 10^{6}$	$-48\ 10^{-3}$
Silicon	$23\ 10^{6}$	$-75\ 10^{-3}$
Glass	$10^{10}\ 10^{14}$	
Rubber	10^{13}	
Sulfur	10^{15}	
Fused Quartz	$76\ 10^{16}$	

Practical Work: 03

Thévenin's Theorem

1. Theoretical Recall

Thevenin's theorem was possibly demonstrated by the German scientist Hermann von Helmholtz in 1853, and then in 1883 by the French telegraph engineer Léon Charles Thevenin. It is used to convert a part of a complex network into a simpler dipole. Any sub-network of a network can be replaced by a voltage generator called (E_{TH}) and a resistor in series with this generator called (R_{TH}).

2. Explanation of Thevenin's Theorem

To understand Thevenin's theorem, let's take a simple example of an active resistive circuit, presented below. The steps to follow to solve using Thevenin's theorem:

Step 1 - First, remove the load resistance R_{ch} from the given circuit,

Step 2 - Replace all impedance sources with their internal resistance,

Step 3 - If the sources are ideal, short-circuit the voltage source and open the current source. (our case),

Step 4 - Now find the equivalent resistance across the load terminals, known as the Thevenin resistance (R_{TH}),

Step 5 - Draw the Thevenin equivalent circuit by connecting the load resistance R_{ch} and then determine the desired response.

Exemple d'application

Let's consider a simple DC circuit, as illustrated in the figure below (Figure 1), where we need to find the load current I_{ch}. E_1=28V, E_2=7V, R_1=4Ω, R_2=1Ω, and R_{ch}=2Ω.

First, we will disconnect the load R_{ch} from the circuit, then measure the voltage across the circuit terminals. This open-circuit voltage across the terminals will be the source voltage if we consider this entire circuit as a voltage source. This no-load voltage is also called the Thevenin voltage E_{TH}.

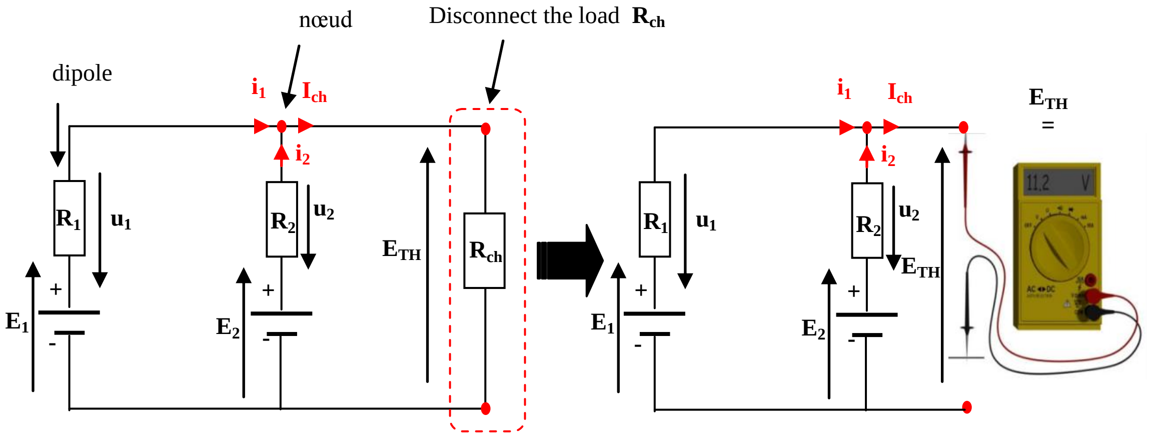

Figure 1. Electrical circuit, for calculating E_{TH}.

$$E_{TH} = E_1 - R_1 i_1 \quad (1)$$

$$E_{TH} = E_2 - R_2 i_2 \quad (2)$$

$$I_{ch} = i_1 + i_2 \quad (3)$$

From the three equations (1), (2) and (3), find the formula for E_{TH}

- **E_{TH}**=……………………………………………………………………………………….

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- Calculate: **E_{TH}**= ………..…V. Answer: **E_{TH}**=11.2 V

We will now calculate the resistance between the terminals.

The measured or calculated equivalent resistance of the circuit at the terminals is called the Thévenin equivalent resistance R_{TH}.

Mathematically, this can be done by replacing the individual sources with their internal resistance. In the case of an ideal voltage source, we can do this by replacing the individual voltage source with a short circuit. (Figure 2).

The load R_{ch} is still disconnected.

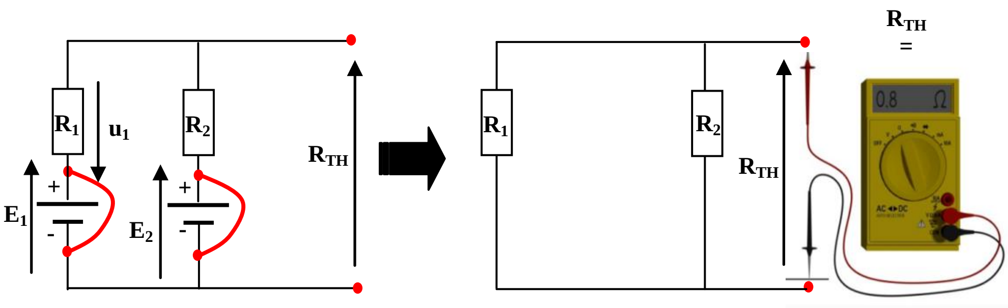

Figure 2. Electrical circuit, for calculating R_{TH}.

From Figure 2, find the formula for R_{TH}

- **R_{TH}**=(R_1//R_2)=……………………………………………………………………………

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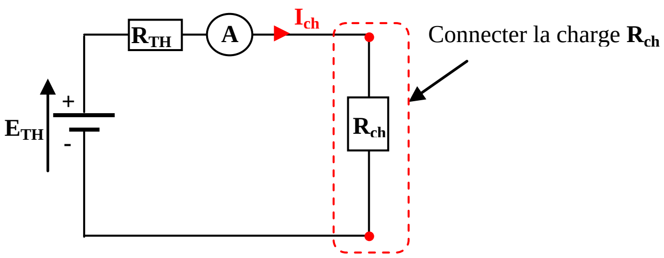
- **Calculate:** R_{TH}= ………Ω. **Answer:** R_{TH}=0.8 Ω

This transformation allows replacing a part of a network with a voltage generator that is electrically equivalent to it, in order to simplify subsequent calculations.

Now, the entire circuit or active network is a Thevenin voltage source E_{TH} with a Thevenin resistance R_{TH} connected in series. (Figure 3).



$$I_{ch}=\frac{E_{TH}}{R_{TH}+R_{ch}}$$

Figure 3. Electrical circuit, for calculating I_{ch}.

- Calculate: I_{ch}=……………….A.

Answer: **I_{ch}=4A**.

3. Objective of this Practical Work

The objective is to define a set of methods for studying an electrical circuit traversed by direct currents.

Verification of Thevenin's theorem for a resistive network, with measurement of the Thevenin generator voltage E_{TH} and its internal impedance R_{TH}.

4. Purpose of the Experiment

The purpose of this practical work is to determine the Thevenin Equivalent Model of an electronic circuit as seen from points A and B.

Replace a complex circuit with a circuit composed of a voltage source and a resistor.

5. Concepts and Preparation Work

Consider a circuit consisting of two voltage sources (E_1 and E_2 (V)) connected to a resistor R (Ω) (expressed in ohms) for each, using conducting wires, the whole supplying a resistive load R_{ch} (Figure.1).

Read and prepare the application example above well.

6. Practical Part

6.1. The Thevenin Voltage E_{TH}

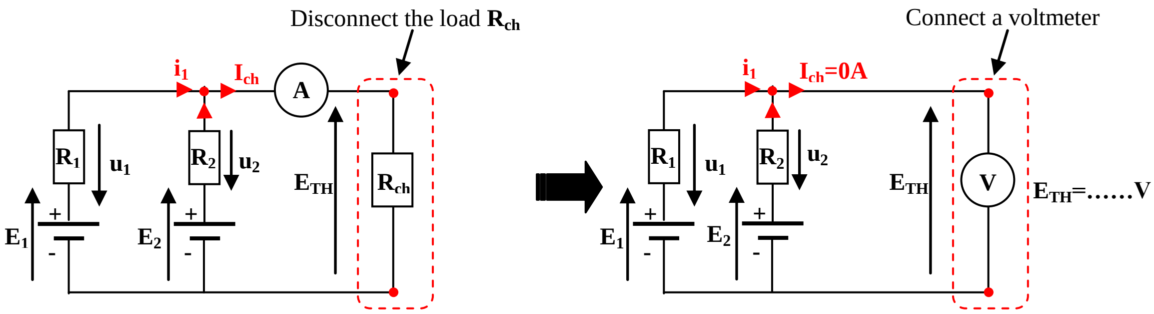
- Assemble the circuit of Figure 4 (a) with the load resistor R_{ch} connected, with:

E_1=28V,

E_2=7V,

R_1=4Ω,

R_2=1Ω, and R_{ch}=2Ω.



.a. with load R_{TH}. .b. Without load R_{TH}.

Figure 4. Electrical circuit, for calculating E_{TH}.

- The reading on this ammeter gives us the load current: Figure 4(a)

I_{ch}=…………………….A.

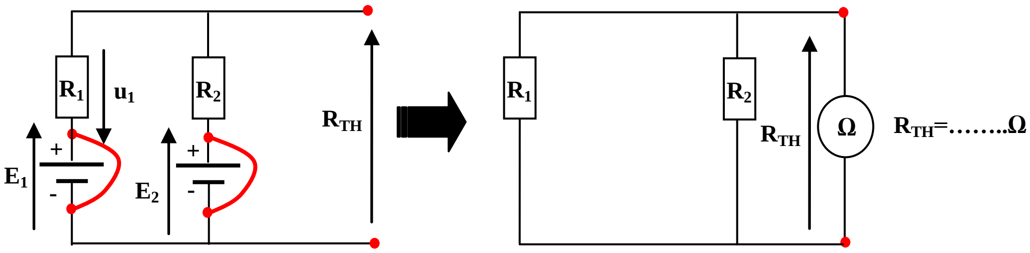
- Remove the load R_{ch} and replace it with a voltmeter across the terminals. Figure 4(b)
- The reading on this voltmeter gives us: Figure 4(b)

E_{TH} =…………………V.

6.2. The Thevenin Resistance R_{TH}

- Now, short-circuit the generator (source) and place an ohmmeter between the terminals. Figure.5(a).
- The reading on this ohmmeter gives us: Figure 5(b).

R_{TH} =………..……Ω.



a. Short circuit the generator **b.** Without generator with ohmmeter

Figure 5. Electrical circuit, for calculating R_{TH}.

6.3. Comparison between results

- Complete the table below:

	Theoretical Results	Practical Results
E_{TH} (V)	….	….
R_{TH} (Ω)	….	….
I_{ch} (A)	….	….

- Interpret the obtained results

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7. Conclusion

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Practical Work: 04

The Oscilloscope

1. Theoretical Recall

The oscilloscope is a measuring instrument (voltage measurement) that allows the visualization of the measured voltage on a graduated screen along two axes:

The vertical axis (voltage in volts) has ten divisions and the horizontal axis (time in seconds) also has ten divisions. Each division is divided into five sub-divisions.

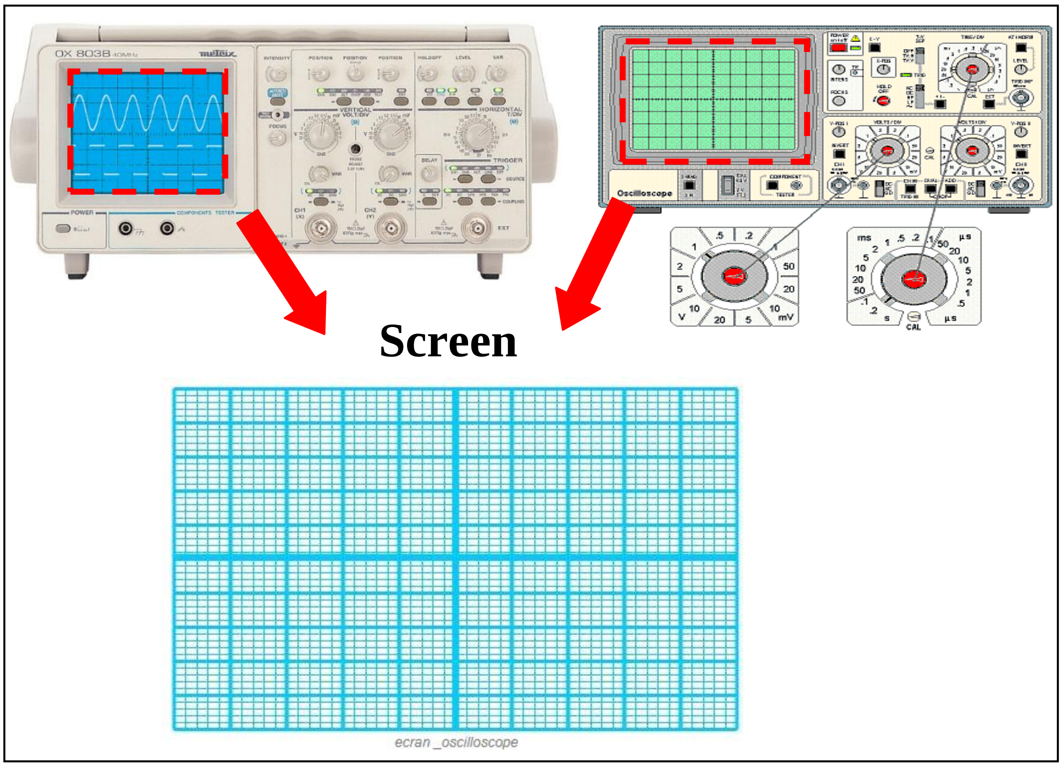

Figure 1. Oscilloscope.

The oscilloscope has 2 inputs, CH1 and CH2, with the input impedance of each input being: (R_{input}= 1 MΩ, C_{input}= 20 pF). These two inputs can be displayed on the screen separately by using the CH I/II button or together by using the (Dual) button. We can also add these two inputs, if needed, by pressing the (ADD) button.

Each input of the oscilloscope can be used in one of the following three modes:

- GND mode (ground),
- AC mode (alternating coupling),
- DC mode (direct coupling).

2. Operating Principle

An oscillogram corresponds to the curve generated by the movement of a luminous spot on the screen of a cathode ray tube. It can correspond to the evolution of a quantity as a function of time or to the evolution of one quantity relative to another (signal composition).

Example:

$V_1(t) = V_{1Max}*\sin(100\pi.t)$ $V_2(t) = V_{2Max}*\sin(100\pi.t-\pi/3)$ such as: $V_{1Max} > V_{2Max}$

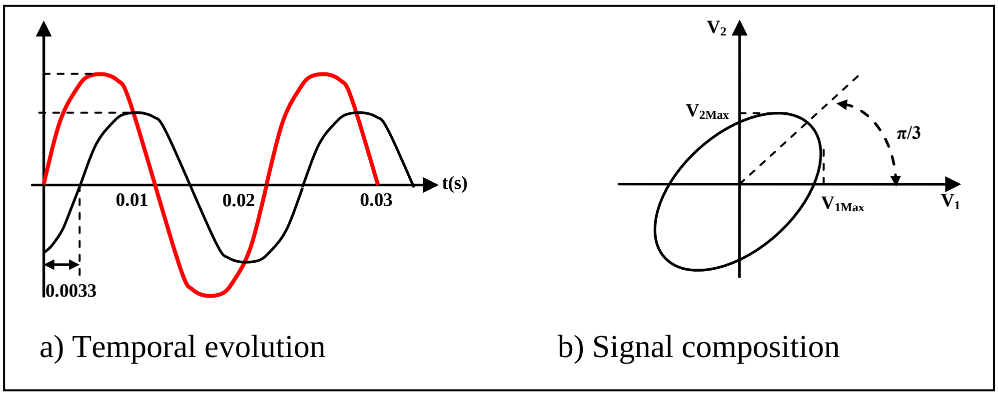

Figure 2. Oscillograms of signals V_1 and V_2

The cathode ray tube of an oscilloscope (or a television) is a large glass bulb, evacuated of air, containing an electron gun (figure 3).

The electron gun consists of a heated metal cathode from which electrons are extracted by the electrical attraction exerted by an anode.

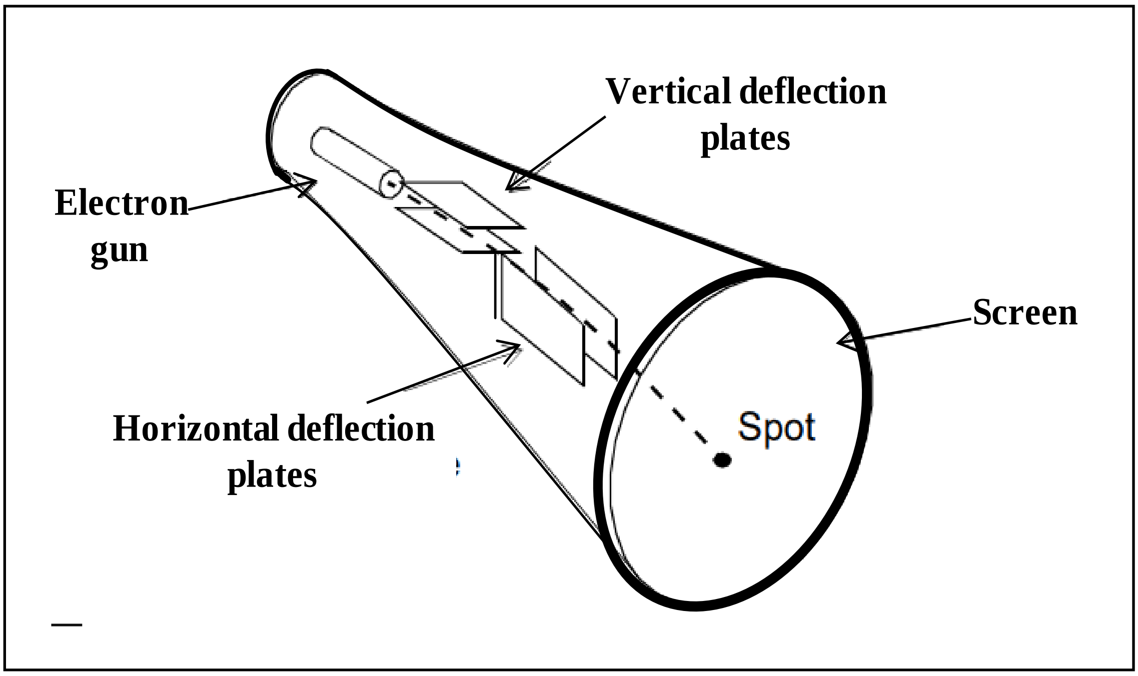

Figure 3. The cathode ray tube.

Figure 4 shows two oscillograms as they will appear on the oscilloscope screen by imposing the following forms for $V_1(t)$ and $v(t)$.

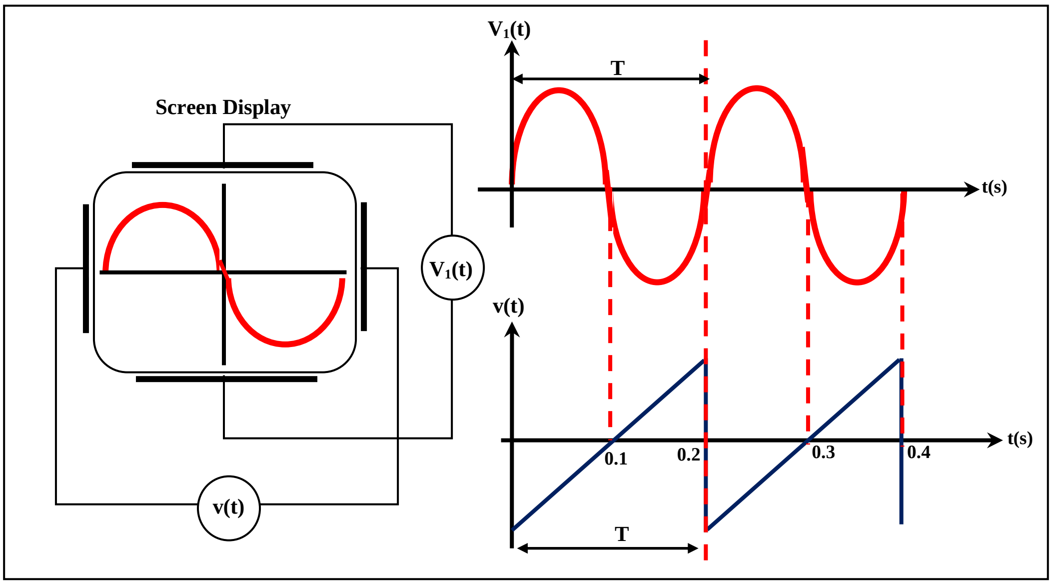

Figure 4. Tracing an oscillogram on the screen.

3. The Objective of this Practical Work

The objective of this practical work is to know how to use an oscilloscope to measure physical quantities such as voltage, period, frequency, and phase difference.

4. Aim of the Experiment

The aim of this work is to handle the oscilloscope and the LFG (Low Frequency Generator). Through:

- Knowing how to use the multiple controls visible on the front panel of each device.
- Knowing how to perform measurements of amplitude (voltage), frequency, and phase difference.

5. Preparation Work

Before coming to the laboratory, try to read and prepare the practical work, discuss the following points:

- Definition and description of a cathode ray oscilloscope,
- Operating principle and field of use of an oscilloscope,
- Handling and use of an oscilloscope.

6. Procedure

6.1. Equipment Used

- A Cathode ray oscilloscope,
- A DC (direct current) and AC (alternating current) voltage generator,
- A Low Frequency Generator (LFG),

- Resistance boxes and capacitor,
- Voltmeter (or multimeter).

Before starting:

- Identify on the oscilloscope the buttons that allow:

a) Turning the device on.

b) Adjusting the brightness and sharpness of the "line or spot".

c) Adjusting the sharpness of the "line or spot".

d) Centering the "line or spot" on the screen, in …↔ …… , and in …↕… ……

e) Changing the sweep speed of the spot.

f) Changing the vertical sensitivity of channel A (or 1).

- Identify the inputs for channels A (or 1): YA, Y1 or CH1 and B (or 2): YB, Y2 or CH2.

6.2. Mesure d'une tension continue Measuring a DC Voltage

Given the following setup:

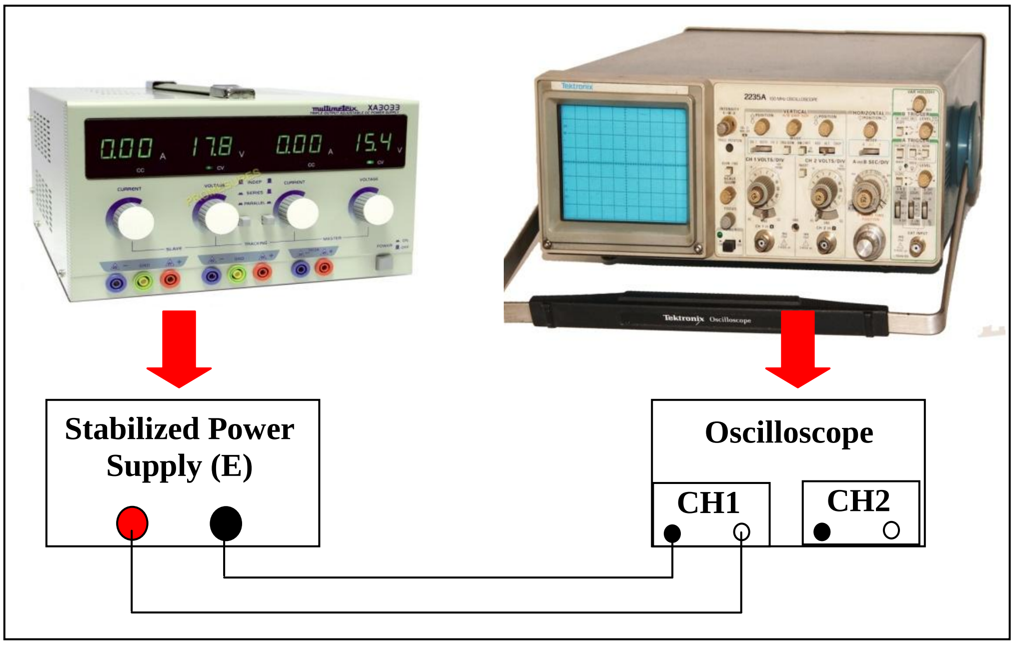

Figure 5. Setup 01 in DC mode.

According to the oscilloscope settings, record:

- The time base used for this application
- Measure with a voltmeter (or multimeter) the value of E= ……V.
- Connect the oscilloscope to the generator according to the setup indicated in figure 5.
- Operate the oscilloscope, then adjust the axes, the origin of the axes, the luminous spot, etc.
- Draw the obtained signal, with the oscilloscope in the DC position.

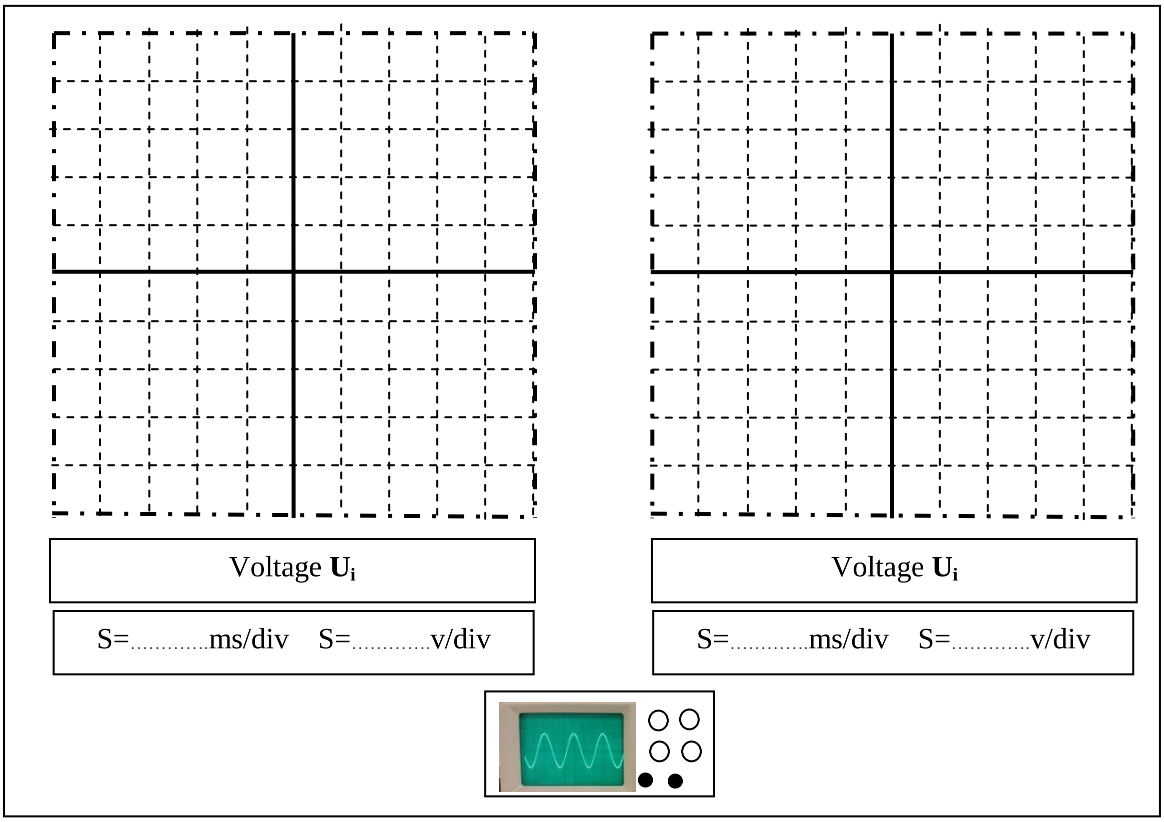

Figure.5. Output voltage using the oscilloscope.

- Vary the output voltage of the generator and observe the obtained signal. Fill in the following table:

Value read on the generator display or voltmeter	Value measured on the oscilloscope

- Note your observations and comments.

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6.3. Measuring Frequency and Period

Recall that the frequency f=1/T where T is the period of the signal.

Given the following setup:

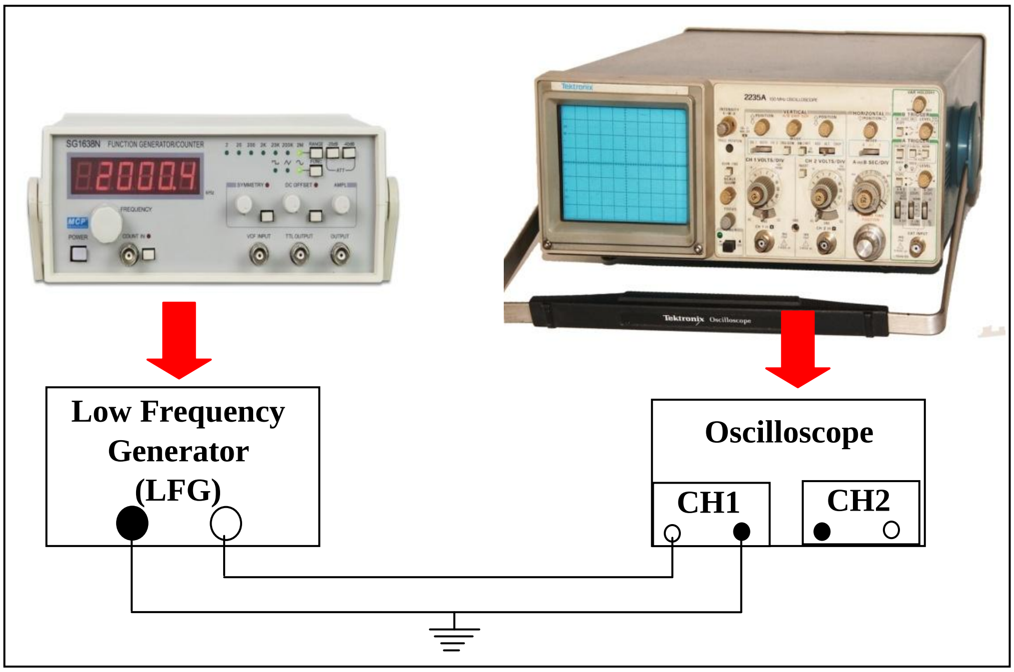


Figure 6. Setup 02 in AC mode.

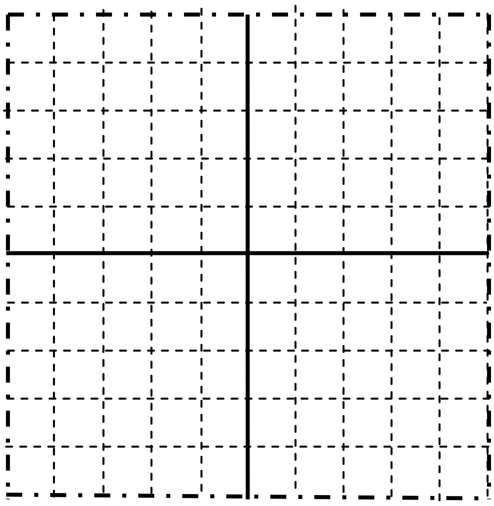
- Do the same work for an alternating generator.

Using the LFG, select a sinusoidal signal, then fill in the following table:

- Measure the peak-to-peak amplitude (U_{pp}), the maximum value U_{max}, the period *T*, and the frequency f?
- What does the value measured by the voltmeter (or multimeter) signify in the three cases?

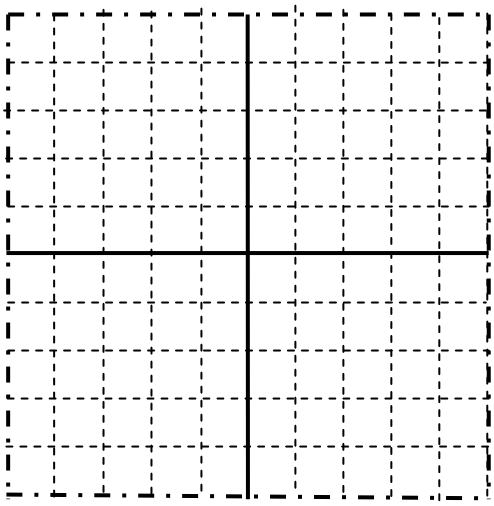
	Sinusoidal Signal	**Square Signal**	**Sawtooth Signal**
U_{max} (V)			
U_{pp} (V)			
$U_{voltmeter}$ (V)			
Period (T)			
Fréquency (Hz)			

- Draw the obtained signal, with the oscilloscope in the AC position.



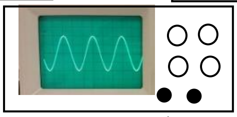
Voltage U_i Sinusoidal Signal

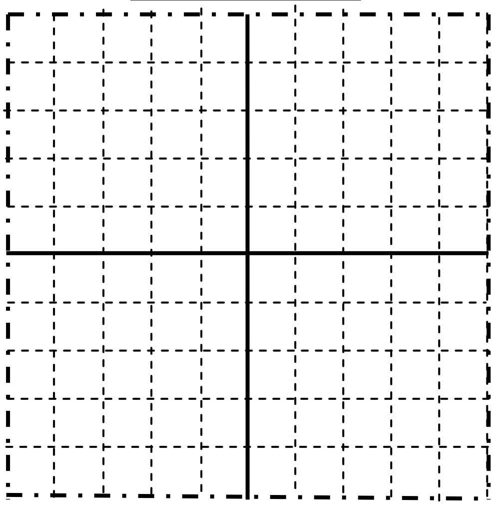
S=.............ms/div S=.............v/div



Voltage U_i Square or Rectangular Signal

S=.............ms/div S=.............v/div





Voltage U_i Sawtooth or Triangular Signal

S=.............ms/div S=.............v/div

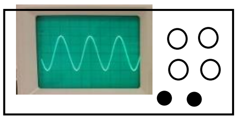


Figure 6. AC output voltage using the oscilloscope.

- Vary the output voltage of the generator, observe and draw the obtained signal.

7. Conclusion

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Practical Work: 05

Practical Work on Magnetism
(Transformer)

1. Theoretical Recall

An electrical transformer is a static electrical machine that allows modifying the voltage and current intensity values delivered by an alternating electrical energy source into a system of voltage and current with different values, but with the same frequency and same shape. It performs this transformation with excellent efficiency.

Based on Lenz's law, it only works with alternating current. The following figures represent the symbols of the most commonly encountered transformers:

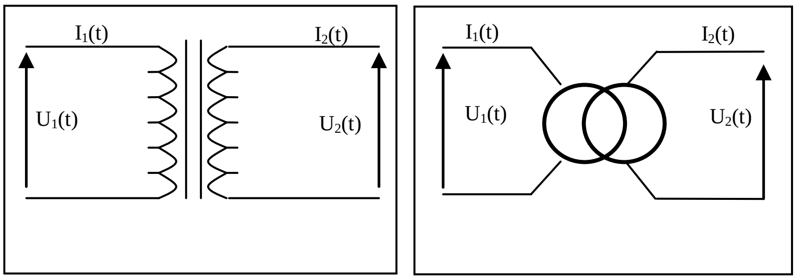

Figure 1. Symbols of a single-phase transformer.

- The primary winding is the one that is powered,
- The secondary winding is the one that supplies the load,

2. Construction of Single-Phase Transformers

A transformer consists of a magnetic circuit, composed of laminations stacked on top of each other. On one column of this magnetic circuit, a winding made of turns of conductive wire is placed. This winding is called the primary winding of the transformer. A second winding is wound on the magnetic circuit. It is called the secondary winding of the transformer. The no-load secondary voltage is proportional to the primary voltage.

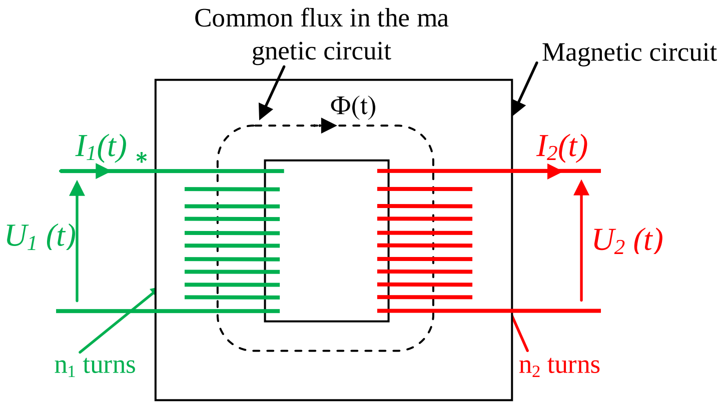

Figure 2. Construction of a single-phase transformer.

3. The Objective of this Practical Work

- Study the operating principle of a transformer and its applications.
- Build a rectifier circuit using diodes.

4. Goal of the Experiment

- Demonstrate the transformation by stepping up or stepping down voltages.
- Transform an alternating signal into a direct signal.

5. Concepts and Preparation

Figure 3 schematically represents a transformer. The parameters on the left side are those of the primary, while those on the right represent the secondary. By applying a sinusoidal voltage to the primary circuit consisting of a winding of "n_1" turns, what happens on the secondary of "n_2" turns?

Let the primary voltage be $U_0 \sin(\omega t+\theta)$. The current flows through the primary winding around the ferromagnetic core, it will create a magnetic flux Φ in the iron which will in turn induce an electromotive force "e.m.f" given by the relation:

$$E_{in} = -n_1 \frac{d\Phi}{dt}$$

For an ideal transformer, the primary voltage U_1 is equal to the induced "e.m.f".

$$E_{in} = -U_1 = -U_0 \sin(\omega t + \theta)$$

For reasons of high efficiency, the iron core is made of a stack of varnished laminations. Under these conditions, the flux Φ is completely channeled in the iron and will be recovered in the secondary, where it will create an e.m.f. which, in the case of a no-load transformer, will be equal to the voltage delivered by the secondary winding.

$$U_2 = V_0 \sin(\omega t + \beta)$$

Furthermore: $$U_2 = n_2 \frac{d\Phi}{dt}$$

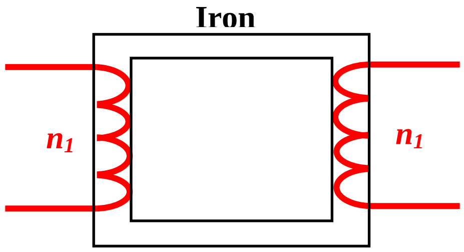

Figure.3. Transformer.

1. Since the flux is conserved, derive the following relation:

$$\frac{U_1}{n_1} = \frac{U_2}{n_2}$$

……
……

Thus, we find the expression for the output voltage (that of the secondary) given by:

$$U_2 = \frac{n_2}{n_1} U_1 = mU_1$$

"m" is the transformation ratio.

2. What is the condition on "m" for the transformer to be a step-up transformer?

m=...

3. What is the condition on "m" for the transformer to be a step-down transformer?

m=..

4. What is a diode?

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6. Procedure

- Assemble the circuit shown in figure 4.
- Power the circuit with a voltage V=4.5 V, keeping it constant throughout the experiment.
- Pour un enroulement primaire fixe de $n_1 = 300$ spires, relever la tension du secondaire.
- For a fixed primary winding of $n_1=300$ turns, measure the secondary voltage.

n_2 *(turns)*	14	42	84	112	140
$U_2 (Volts)$					
$\frac{U_2}{U_1}$					
$\frac{n_2}{n_1}$					

1. Complete the table above.

2. Compare the voltage ratios and the winding ratios.

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3. Comment

……………………………………………………………………………………………...
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3.1. Take a fixed primary winding $n_1=300$ turns, and take a fixed secondary winding $n_2=42$ *turns*.

❖ Measure the secondary voltage, U_2=………………*V*, give the value of "*m*=……………......".

3.2. Now reverse the windings so that the primary becomes the secondary.

❖ Measure the secondary voltage U_2=……......……*V*, give the value of "*m*=……………………….".

❖ What do you observe in both cases (A and B)?

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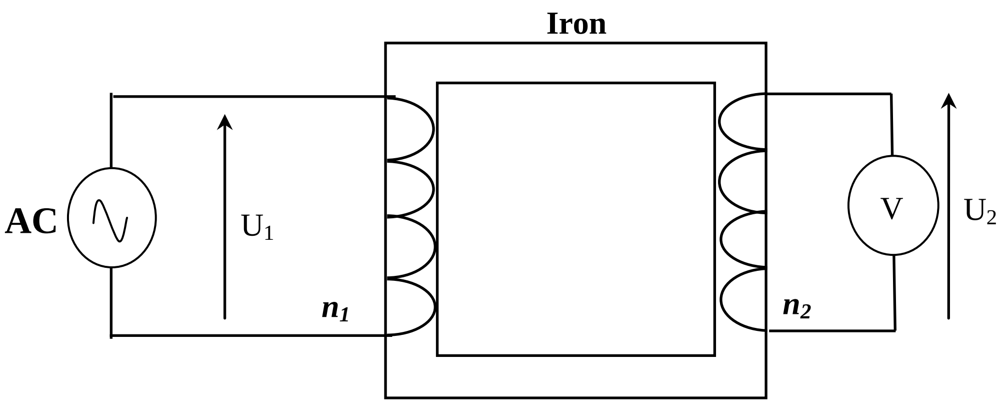
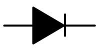


Figure 4. No-load Transformer.

3.3. To transform the output alternating signal into a direct signal, a rectifier is connected to the output of the transformer, as shown in figure 5.

- Take a fixed primary winding $n_1=300$ *turns*.
- Take a fixed secondary winding $n_2=42$ *turns*.
- Using an oscilloscope to visualize the output signal before and after rectification, observe and plot the signals.

Note :  is the electronic symbol for the diode.

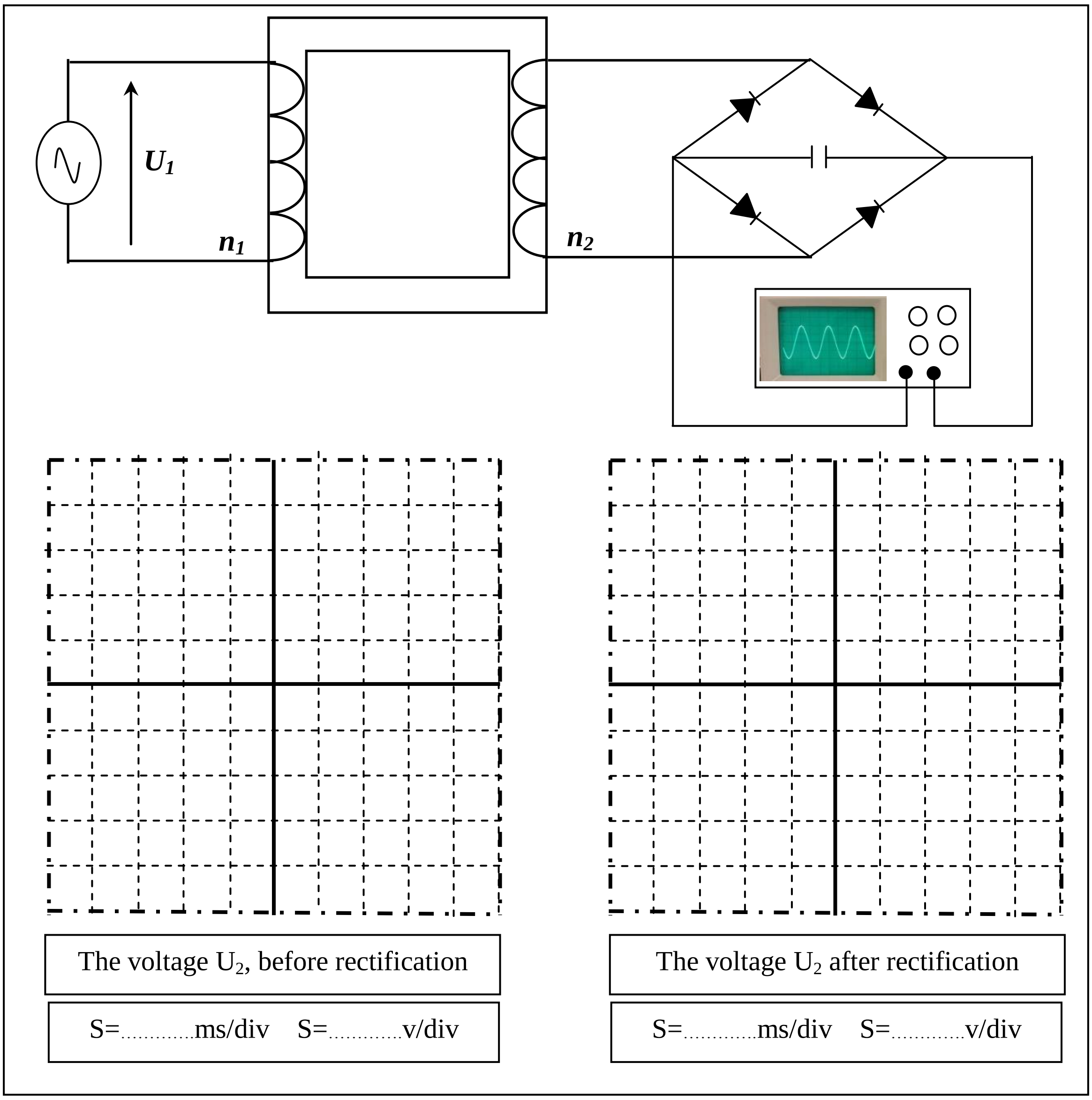


Figure.5. TTransformer + Rectifier with filtering.

7. Conclusion

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Annex
Application Exercises
Moodle Platform

I. Application Exercises for Lab Work: Kirchhoff's Laws

Exercise 1:

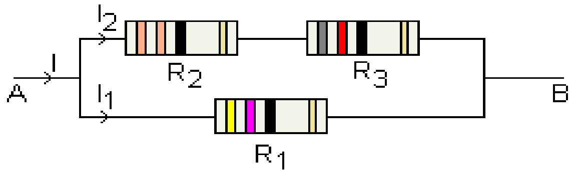
We have two resistors: R_1=100Ω and R_2=220Ω.

- What is the equivalent resistance for their series association?
- What is the equivalent resistance for their parallel association?

Exercise 2:

The circuit shown is built with R_1=47Ω, R_2=33Ω and R3=82Ω.

A voltage U_{AB}=12V is applied between terminals A and B.



- What is the intensity I_{11} of the current flowing through R_1?
- What is the intensity I_{22} of the current flowing through R_2?

Deduce the voltage across resistor R_3.

- Calculate the value of the intensity I of the current in the main branch.

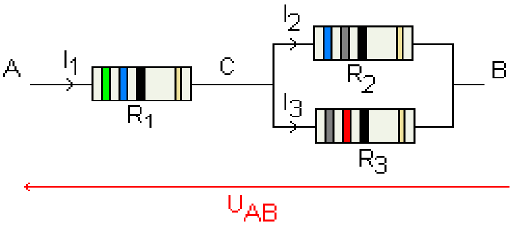
Deduce the value of the equivalent resistance R of the circuit.

- Find the value of R using the laws of association of ohmic conductors.

Exercise 3:

The circuit shown is built with R_1=56Ω,R_2=68Ω and R_3=82Ω.

A voltage U_{AB}=6V is applied between terminals A and B.



- Calculate the equivalent resistance R of the AB dipole.
- Determine the intensity of the current I_{11} flowing through R_1.
- Calculate the voltage U_{AC}.
- Calculate the voltage U_{CB}.
- Calculate the intensities I_{22} and I_{33} of the currents flowing through R_2 and R_3.

By applying Kirchhoff's Current Law, verify the value of I_{11}found previously.

I. Application Exercises for Lab Work: Kirchhoff's Laws

MCQ:

1. **The resistance of a dipole is…….**

- Its strength,
- Its ability to oppose the flow of current,
- Its durability.

2. **Does a resistor decrease the current intensity?**

- Yes
- No

3. **Ohm's Law: the voltage (u) across a resistor (r) is…….**

- Always zero,
- Equal to the intensity,
- Proportional to the intensity (i) of the current flowing through it.

4. **Can a resistor be placed anywhere in a series circuit?**

- Yes
- No

5. **Do all resistors not have the same electrical resistance?**

- Yes
- No

6. **What is the standardized symbol for a resistor?**

- A triangle,
- A circle,
- A rectangle,
- A circle,
- A square.

7. **The greater the resistance of a dipole, the more…..**

- The voltage increases,
- The intensity of the current flowing through it is strong,
- The voltage across it decreases,
- The intensity of the current flowing through it is weak.

II. Application Exercises for Lab Work: Magnetism (Transformer)

Exercise 1:

A single-phase transformer bears the following indications:

Cross-sectional area of the magnetic circuit: $S=30cm^2$, number of primary turns $n_1=276$.

Nominal conditions: Primary voltage $U_{1n}=220V$, 50Hz

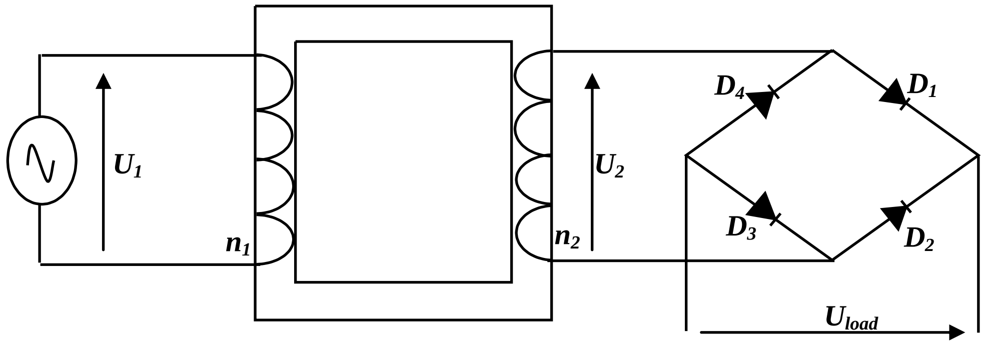
Results of a no-load test: Primary voltage $U_{1v}=U_{1n}=220V$, 50Hz,

Secondary voltage $U_{2v}=33.5V$

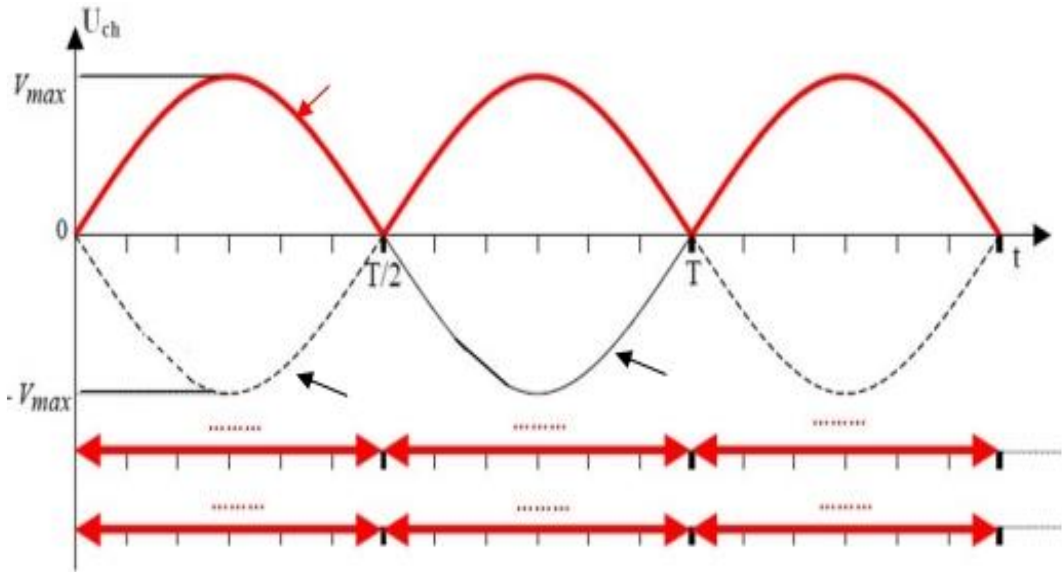
- Determine the transformation ratio "m"?
- Deduce the number of turns "n_2"?

Exercise 2:

The single-phase diode bridge shown is supplied by a sinusoidal alternating voltage $U_2(t)=V_{max}\sin(\omega t)$, $U_2(t)=V_{max}\sin(\omega t)$



- Determine the conduction intervals of diodes D_1, D_2, D_3, D_4? (Complete the areas marked in red)?



II. Application Exercises for Lab Work: Magnetism (Transformer)

Exercise 2:

Complete the following sentences using words chosen from the list below: current, step-down, voltage, electronic, step-up.

1. The purpose of a transformer is to modify the amplitudes of alternating electrical quantities: it transforms signals of .... and current of a given frequency into signals of the same frequency but with different RMS values.

2. The electrical circuit connected to the generator is called the primary circuit, the one connected to the receiver is called the secondary circuit.

Let us call U_1 the RMS value of U_1 at the primary and U_2 the RMS value of U_2 at the secondary then:

- If $U_1<U_2<U_2$, the transformer is said to be .... of voltage,
- If $U_1>U_2>U_2$, the transformer is said to be .... of voltage,

3. The diode is an .... component,

4. The diode is an electronic component with 2 legs, i.e., a dipole, whose particularity and main interest is that it only lets .... flow in one direction.

MCQ Questions:

1. What is the role of a transformer in electricity?

☐ Adapt the water flow rate,

☐ Adapt the voltage,

☐ Lower the frequency.

2. A secondary winding, which, being traversed by the magnetic field produced by the primary, provides:

☐ An alternating current of the same frequency but with a voltage that can be higher or lower than the primary voltage,

☐ An alternating current of different frequency but with a voltage that can be higher or lower than the primary voltage,

☐ An alternating current of the same frequency and the same voltage.

3. A transformer that increases the voltage is called:

☐ Step-up transformer,

☐ Step-down transformer,

☐ Voltage adapter.

4. In a single-phase transformer, what is the formula to find the transformation ratio 'm'?

☐ $m=N_2/N_1$,

☐ $m=N_1/N_2$,

☐ $m=V_1/V_2$.

5. In the formula '$m=N_2/N_1=V_2/V_1$', what does 'm' mean?

☐ The simultaneity factor,

☐ The transformation ratio,

☐ The utilization factor.

6. The nameplate of a transformer indicates:

50Hz, 220V / 110V, 1100VA. The transformation ratio is:

☐ 2,

☐ 0.5,

☐ It cannot be calculated.

7. If the input voltage of the rectifier is a sinusoidal voltage with a frequency of 50 Hz. What is the frequency of the rectified voltage?

☐ 16 Hz,

☐ 23 Hz,

☐ 50Hz,

☐ 100Hz.

8. Given a signal with an RMS value of 220 V. Assuming the load is a pure resistance, what is the average value of the rectified voltage across the load?

☐ 105V,

☐ 99V,

☐ 330V,

☐ 100Hz.

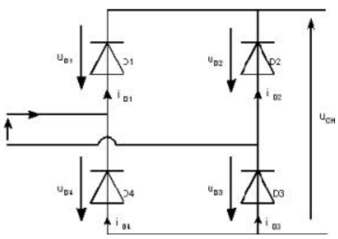
9. For the circuit below, which diodes have common anodes?

☐ Diodes D1 and D4,

☐ Diodes D2 and D3,

☐ Diodes D1 and D2,

☐ Diodes D3 and D4.



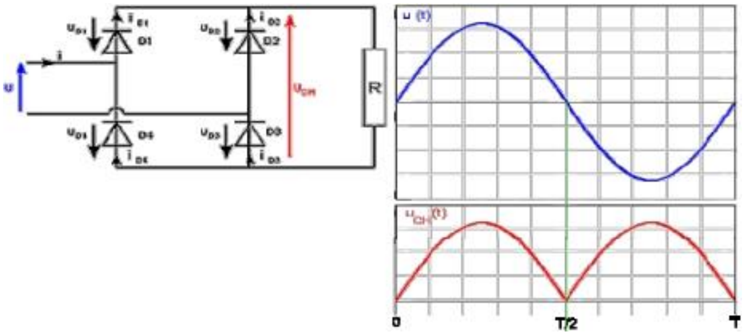
10. For $0<t\leq T/2$; which diodes are conducting?

☐ D2 and D3,

☐ D3 and D4,

☐ D1 and D2,

☐ D1 and D3.



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[2] https://fr.wikipedia.org/wiki/Transformateur_%C3%A9lectrique

[3] https://www.academia.edu/6767244/Cours_de_Transformateur_pour_Etudiant_et_ingenieur

[4] http://numlor.fr/elearning/etenp/co/2PD2NC.html

[5] http://numlor.fr/elearning/etenp/co/4FiltrageCapacitif.html