Democratic and Popular Republic of Algeria
Ministry of Higher Education and Scientific Research
University Mustapha Stambouli of Mascara
Faculty of Science and Technology
Common Core Department of Science and Technology

Course Handout

Physics II
Electricity and magnetism Experiment

Instructor : Dr. BELOUFA Abbes

This handout is intended for first-year students Science and Technology Licence

Algérie
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Department of Common Core
Science and Technology

Experiment Physics II

Année 2024

Foreword

Strictly in accordance with the new program, this experiment handout is aimed at all first-year LMD students, field science and technology (ST). As such, it is addressed also money to *teachers,* to whom it provides useful methods for the experiment

Each Lab is divided into two complementary parts.

- ❑ The basic theory, which presents the main reasoning to understand and know, accompanied by numerous direct applications.
- ❑ The manipulations, they are of an easy to medium level.

This document is accompanied by the bibliography used.

This manuscript is composed of seven experiments

We hope that this book can effectively help a majority of students.

Given the length of this document, there may be errors of all kinds. If the reader encounters any, he can report them to me at a_beloufa@yahoo.fr

Education Programs

PROGRAM OF MODULE :

Experiments of Physics II (Electricity and Magnetism)

Experiment n°1 : Overview of the most common electrical measuring instruments

Experiment n°2 : *Kirchhoff's Laws (KVL-KCL)*

Experiment n°3 : Thevenin's theorem

Experiment n°4: *Capacitors, Inductors and their assemblies*

Experiment n°5 : *Capacitor Charging and Discharging*

Experiment n°6 : Oscilloscope

Experiment n°7 : Magnetism

The experiments handout of physics II (electricity and magnetism) will be limited with the materials witch exists in the lab of physics of university Mustapha Stambouli of mascara. Farthrmore; the experiments of Wheatstone Bridge has inclued

Experiment n°8 : Wheatstone Bridge

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%

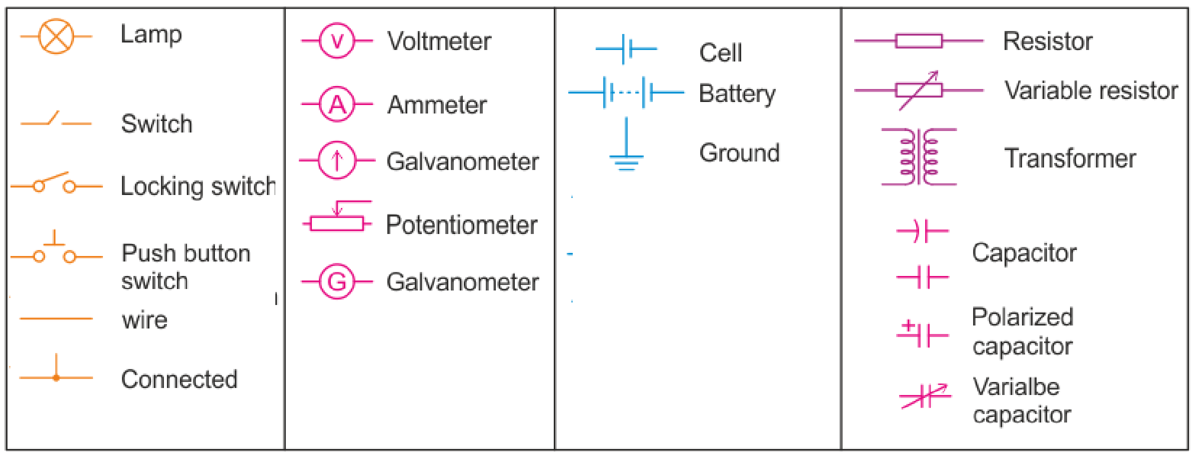
Symbols and Units of Electrical Quantities

I. Basic electrostatic concepts, symbols and units

Table 1. Basic electrostatic concepts, symbols and units.

Physical Quantity	Symbol	SI System	Unit Abbreviations
Electric field	E	Volt/meter	–
Electric potential	V	Volt	V
Electric charge	Q,q	Coulomb	C
Electric current	I,i	Ampere	A
Power	P	Watt	W
Current density	J	Ampere/meter^2	–
Magnetic field	B	Tesla	T
Resistor	R	Ohm	Ω
Capacity	C	Farad	F
Inductance	L	Henry	H

II. Symbols of Some Circuit Elements



III. Analog and Digital Instruments

Analog and Digital Instruments Analog measuring instruments are instruments that show the measured value with a pointer on divisions of the scale. Although the mechanism of such measuring instruments seems simple, it is possible to make more precisely measurement.

IV. Calculated errors for some commonly used functions

Process	Absolute error (Uncertainty)
$y = a + b \quad or \quad y = a - b$	$\Delta y = \sqrt{\Delta a^2 + \Delta b^2}$
$y = ab \quad or \quad y = a/b$	$\frac{\Delta y}{\bar{y}} = \sqrt{\left(\frac{\Delta a}{\bar{a}}\right)^2 + \left(\frac{\Delta b}{\bar{b}}\right)^2}$
$y = \lambda a^n$	$\frac{\Delta y}{\bar{y}} = \lvert n \rvert \frac{\Delta a}{\bar{a}}$
$y = \lambda \ln \mu a$	$\Delta y = \lambda \frac{\Delta a}{\bar{a}}$

V. Systematic Errors:

These errors are caused by the measuring instruments used, the method followed in the experiment and external influences. Accuracy can be consider as the measure of systematic error that reveals the difference of the measured value from the true value.

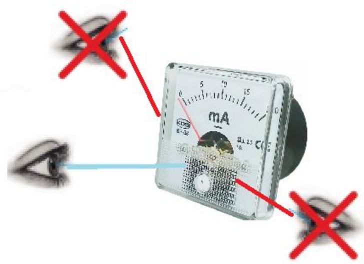


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TABLE OF CONTENTS

Laboraty safety rules for students

Laboraty safety rules for students

Students are required to make themselves aware of the Rules for each Laboratory they are using.

When working in the laboratory the following rules should be followed:

- Conduct yourself in a responsible manner at all times in the laboratory.
- Follow all written and verbal instructions carefully.
- Students are required to arrive promptly, at least 15 minutes before the start of the session. Any voluntary delay will result in entry refusal, a zero grade for the practical work, and the student will not be entitled to a resit. Punctuality is crucial, and adherence to the specified timing is mandatory for successful participation in the practical session.
- Attendance at TP session is compulsory. Any absence must be justified within 48 hours after the occurrence. Submit the justification to the secretariat, including the original and a copy of this certificate; will be given as soon as possible to the group leader. Otherwise, the student is penalized with a 00/20 and does not have the right to retake

- Do not eat food, drink beverages, or chew gum in the laboratory.
- Students must wear a lab coat at all times inside of the lab
- All the students to note that they will not be allowed to enter the lab without an instructor present.
- Students are never permitted in the science storage given specific permission by their instructor.
- When first entering a science room, do not touch any equipment in the laboratory area until you are instructed to do so.
- Conduct yourself in a responsible manner at all times in the laboratory.

- Do not lean, hang over or sit on the laboratory tables.
- Keep aisles clear. Push your chair under the desk when not in use.

- Please ensure that you bring the following items for the practical work session and report: Pen, Pencil, Eraser, Calculator, Millimeter sheets, Ruler and Double 21×27 sheet (for the report)

- Do not start the experiment until you have been instructed to do so by your Teacher. You may need to receive specific safety instructions for the experiment from your Teacher, or they may need to provide additional information that will help you in performing the experiment well.
- Do not attempt unauthorized experiments or procedures.
- Never change wiring with circuit plugged into power source.
- Never hurry. Haste causes many accidents.
- All current transmitting parts of any electrical devices must be enclosed.
- Unplug cords by gripping the plug end, do not pull on the cord.
- Work areas should be kept clean and tidy at all times and in good order before leaving the laboratory.

Experiment 1

Overview of the most common electrical measuring instruments

Experiment N°1:

Overview of the most common electrical measuring instruments (Voltmeter and Ammeter; etc...)

I. SPECIFIC OBJECTIVES

In the physics lab, we have a variety of measuring devices that we utilize to measure different parameters. Some of the instruments utilised in the lab include a voltmeter, an ammeter, a multimeter, an ohmmeter, and a galvanometer, among other things. Electricity is measured with the help of instruments such as ammeters and voltmeters. Let us have a look at the ammeter and its specifications in this Lab to gain a better understanding of them.

II. BASIC THEORY

II.1 Analog multimeters

There are two ways to measure electricity; one is by measuring the current where the ammeter is being used and another by measuring the voltage where the voltmeter is being used.

As their names suggest, analog and digital multimeters are differentiated by technology matters. In analog, there is a pointer with parameter scales, where pointer deflection during test tells about readings. On other hand digital multimeters have digital lcd displays, they give results in numbers.

Analog multimeters may be more difficult to read than their digital counterparts, but the continuous movement of the needle allows a more precise monitoring of changes in current and resistance than a digital readout. An analog multimeter generally consists of a screen with a pointer and multiple scales, a range selector and two leads. Connecting the two leads to the positive and negative terminals of an electrical circuit and setting the range selector to the right setting will give an accurate readout of the current in the circuit.

II.2 Rheostat

A rheostat is a variable resistor that is used to control the flow of electric current by raising or lowering resistance.

Figure 1: *Rheostat Symbol*

The term rheostat was coined by the English scientist Sir Charles Wheatstone and is derived from the Greek word "rheos" and "statis" which means the current controlling device.

The focus of this activity is to learn how to appropriately place an ammeter and voltmeter in a circuit and to learn how to read the instrument to obtain a value for current and voltage.

II.2.1 Construction of Rheostat

Rheostat and potentiometer construction is identical. The rheostat has three terminals and two connectors. The following is a diagram of a rheostat's construction:

The rheostat's three terminals are indicated as A, B, and C. A and B terminals or B and C terminals are employed. The resistive element is represented by A and C in the preceding image, which are fixed and attached to the track. Terminal B is uneven and is connected to the slider.

As the wiper moves along the resistive element over the resistive path, the resistance of the rheostat changes. The rheostat's resistive element is made with a loop of wire.

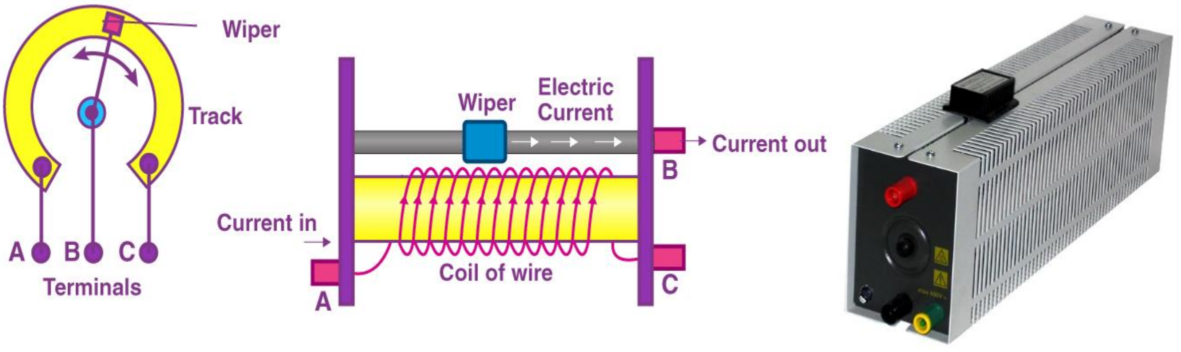

Figure 2:

The resistance of the rheostat is dependent on the length of the resistive path.

II.2.2 Applications of Rheostat

- The rheostat is used as a voltage divider.
- The rheostat also finds applications as a variable resistive load.

II.3 oscilloscope

- In lighting circuits, the rheostats find applications as a dimming device.

An oscilloscope is an electronic test instrument that displays electrical signals graphically, usually as a voltage (vertical or Y axis) versus time (horizontal or X axis) as shown in figure 1. The intensity or brightness of a waveform is sometimes considered the Z axis. There are some applications where other vertical axes such as current may be used, and other horizontal axes such as frequency or another voltage may be used.

II.3.1 Applications

Oscilloscopes are commonly used for measurement applications such as:

- observing the wave shape of a signal
- measuring the amplitude of a signal
- measuring the frequency of a signal
- measuring the time between two events
- observing whether the signal is direct current (DC) or alternating current (AC)
- observing noise on a signalµ

II.4 Generator.

This is the Function Generator. It is used to generate waveforms of specific frequencies and amplitudes. For example, if you needed a sinusoidally varying voltage, you would use this instrument to generate that. The frequency and amplitude can be selected from the front panel options.

Nb Connecting meters

It is important to connect meters the correct way round:

- The **positive terminal** of the meter, marked (+) or coloured red should be connected nearest to (+) on the battery or power supply.

- The **negative terminal** of the meter, marked (-) or coloured black should be connected nearest to (-) on the battery or power supply.

There are only two important things to read a multimeter correctly, which are focusing and

knowing the numbers/symbols. With a little effort and practice, anyone can do it well. We suggest you never try these things without enough education of your teachers. We hope this background study has helped you understand how to read an ammeter and voltmeter

III. Discussion

1°) A……………….of symbols……………., is a device that is used to measure voltage across two points in an electric circuit, it is connected in…………………with the circuit and its accuracy is less.

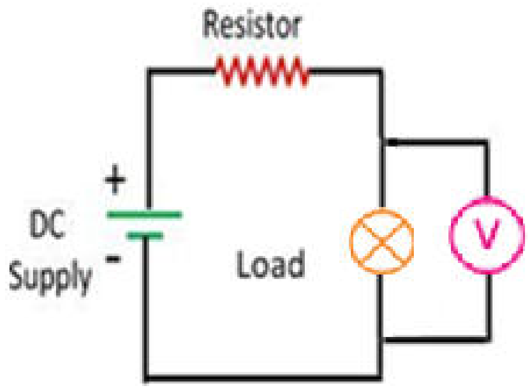

Figure 3:

2°) A…………………..source that is unchanging and constant over time is called a ………………….. While a voltage source that varies periodically in amplitude over time is called an……………………….

3°) An ammeter is an essential device for measuring ....flow of symbols………………………..

It measures the current in ……………., which is a unit of electric current. The intensity of the current, noted……….…... It is connected in ………………..with the circuit and its accuracy is more; Some multimeters have a resolution of milli and micro amps denoted by …… and ……………. respectively.

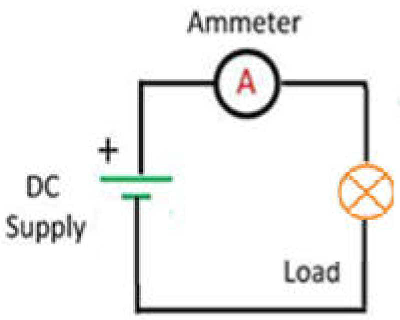

Figure 4:

4°) What does caliber mean ?

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5°) If we know the order of magnitude of the voltage or ampere to be measured, we choose the size just :

- ➢ above the estimated value
- ➢ below the estimated value

6°) If we have no idea of the value order of the voltage or ampere to be measured, we can keep :

- ✓ the highest of the device, then it is reduced.
- ✓ the smallest of the device, then we increase it.

7°) How to Read a Measurement from an Analog Instrument :

Find the right scale on an analog ammter or voltmeter. Analog ammeter or voltmeter have a needle behind a glass window, which moves to indicate the result. Typically, there are two arcs printed behind the needle. These are two different scales, each of which is used for a different purpose:

After connecting meter to the power source check needle movement on screen, you have to count scale lines manually here. For example, if there are 10 lines in a scale of 30 between 0 to 10v that means every line will indicate a change of 1. Similarly, if there are 10 lines in a scale of 100 between 0 to 20, it indicates a change of 2.

For an ammeter, for example, the needle moves on two dials with respective maximum graduations of 30 and 100.

The indication read represents only a number of divisions. It is therefore necessary to deduce the intensity taking into account the caliber.

Calculate the values of i1, i2 and i3, from the readings taken on the two dials, taking into account the sizes chosen for each measurement.

$$value\ mesurad = \frac{caliber \times reading}{scale}$$

a°) Caliber 0.3A :

Scale	Reading	i_1 (A)
30	6	$i_1 = \frac{..\times..}{..}$
100	20	$i_1 = \frac{..\times..}{..}$

b°) Caliber 1A :

Scale	Reading	i_2 (A)
30	15	$i_2 = \frac{..\times..}{..}$
100	50	$i_2 = \frac{..\times..}{..}$

c°) Caliber 3A :

Scale	Reading	i_1 (A)
30	24	$i_3 = \frac{..\times..}{..}$
100	80	$i_3 = \frac{..\times..}{..}$

Summary: From these six measurements, what can we conclude?

a°)
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………

8°) Absolute uncertainty: $\Delta i_{total} = \Delta i_{reading} + \Delta i_{device}$, we consider that :

$$\Delta i_{lecture} = \frac{(^1/_2) graduation \times caliber}{scale}$$

8.1) When reading from the dial of 100, $\Delta i_{reading}$ is then equal to :

☐ $\Delta i_{reading} = caliber/50$ ☐ $\Delta i_{reading} = caliber/100$

why ?…………………………………………………………………………………………..
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8.2) When reading from the dial de 30, $\Delta i_{reading}$ is then equal to :

☐ $\Delta i_{reading} = caliber/30$ ☐ $\Delta i_{reading} = caliber/60$

why ?..
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8.3) Write the expression of Δi_{device} :

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IV. Conclusions ……………………………………………………………………

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Experiment 2

Kirchhoff's Laws
(KVL-KCL)

Experiment N°2:

Kirchhoff's Laws (KVL-KCL)

I. SPECIFIC OBJECTIVES

- *To prove experimentally Kirchhoff's Laws (KVL and KCL) by examining the relationship between the voltage (V) applied between the ends of any resistor and the current (I) passing over this resistor using Ohm's Law*
- *Based on the experimental data, to express the equivalent resistance in a circuit consisting of several resistors connected in series and in parallel.*
- *Verification of kirchhoff's Laws*

II. BASIC THEORY

II.1 Kirchhoff's laws

Kirchhoff's laws are fundamental principles in electrical circuit analysis, helping determine voltages, currents, and resistances within a circuit. There are two laws:

1. Kirchhoff's Current Law (KCL)
2. Kirchhoff's Voltage Law (KVL)

II.1.1 Kirchhoff's First Law or Kirchhoff's Current Law (KCL)

Kirchhoff's junction rule, also known as Kirchhoff's current law (KCL), Kirchoff's first law, Kirchhoff's point rule, and Kirchhoff's nodal rule, is an application of the principle of conservation of electric charge.

Kirchhoff's junction rule states that at any junction (node) in an electrical circuit, the sum of the currents flowing into that junction is equal to the sum of the currents flowing out of that junction

$$\sum_J I_J in = \sum_J I_J out \qquad (2\text{-}1)$$

The Conservation of Charges is the foundation of this law.

$$I_1 + I_2 + I_3 = I_4 + I_5 + I_6$$

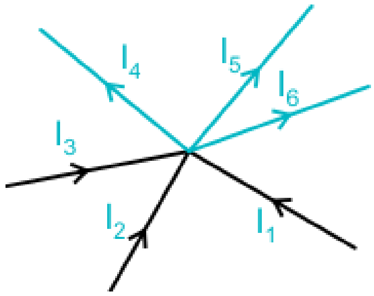


Figure 1:

II.1.2 Kirchhoff's Voltage Law (KVL)

Kirchhoff's loop rule (otherwise known as Kirchhoff's voltage law (KVL), Kirchhoff's mesh rule, Kirchhoff's second law, *or* Kirchhoff's second rule) is a rule pertaining to circuits, and is based on the principle of conservation of energy.

The algebraic sum of the products of resistances of conductors (and currents in them) in a closed loop is equal to the total electromotive force available in that loop. Mathematically, Kirchhoff's loop rule can be represented as the sum of voltages in a circuit, which is equated with zero:

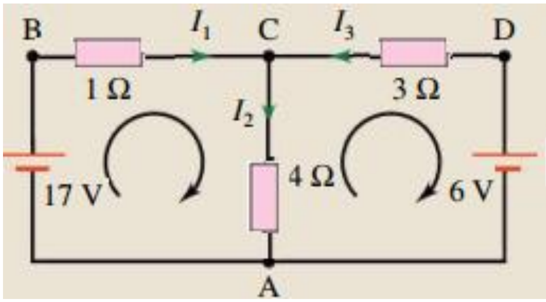


Figure 2:

$$\sum_{i=1}^{n} U_i = 0 \qquad (2\text{-}2)$$

Or

$$\sum_J R_J . I_J - \sum_J E_J = 0 \qquad (2\text{-}3)$$

II.2. Resistors

A resistor is a primary type of physical component that is used in electronic circuits. It has two (interchangeable) leads. The material placed internally between the two leads of a resistor opposes (restricts) the flow of current. The amount of that opposition is called its resistance, which is measured in ohms (Ù). Resistors are used to control the various currents in areas of a circuit and to manage voltage levels at different points therein by producing voltage drops. When a voltage is applied across a resistor, current flows through it.

II.2.1 Ohm's Law

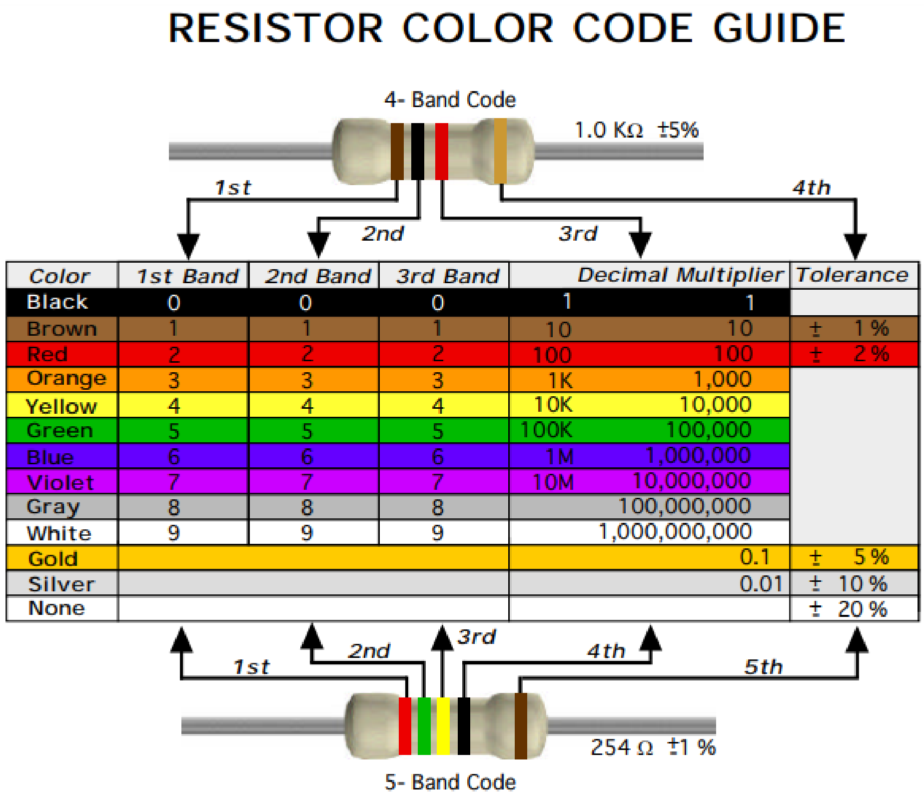
Ohm's law is used to relate voltage to current and resistance. It states that voltage is directly proportional to current and resistance.

$$U = R.I \qquad (2\text{-}4)$$

This is stated mathematically as where *V* is the voltage across an element of the circuit in volts, *I* is the current passing through the element in amps and *R* is the resistance of the element in ohms. Given any two of these quantities Ohm's law can be used to solve for the third.

What is a Resistor Color Code?

These color bands of the resistor are called resistor color codes. Each resistor has different color bands on it that denote the electrical resistance. He color bands on the resistor specified the resistance value, rate of tolerance & sometimes failure rates, or the reliability. The resistor color bands range from 3 to 6 where the first two bands specify the value of resistance & the third band is a multiplier.



Color	1st Band	2nd Band	3rd Band	Decimal Multiplier	Tolerance
Black	0	0	0	1 1	
Brown	1	1	1	10 10	± 1 %
Red	2	2	2	100 100	± 2 %
Orange	3	3	3	1K 1,000	
Yellow	4	4	4	10K 10,000	
Green	5	5	5	100K 100,000	
Blue	6	6	6	1M 1,000,000	
Violet	7	7	7	10M 10,000,000	
Gray	8	8	8	100,000,000	
White	9	9	9	1,000,000,000	
Gold				0.1	± 5 %
Silver				0.01	± 10 %
None					± 20 %

Figure 2:

II.2.2 Translate colors to numeric value

To translate color code to numerical value we will follow the following steps:

1. Place the resistor in the correct position so that the tolerance color band is on the right. Most of the time the resistance tolerance is 10% and the band is Silver in color, easily distinguishable.
   - Tolerance can be defined as the error percentage within the resistance value. So, it is how much we can be expecting for an actual measurement of the resistor.

The resistance would stay with the bands

Example:

Red Black Yellow Violet Grille

2. Translate the first two color bands to numbers. In the case of the example resistor the colors are red and black.

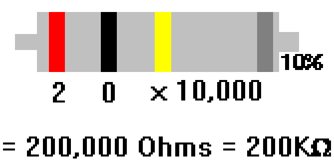


Figure 3:

Red= 2

Black = 0

So the first number is 20

3. Translate the third color band to a multiplier

   Yellow band = 4 zeros = multiplier x 10000
4. Multiply the first number by the multiplier to calculate the final value.

   20 x 10000 = 200000 Ohms=200 KΩ

Remember the color codes with this sentence:

Big Brown Rabbits Often Yield Great Big Vocal Groans When Gingerly Slapped.

II.3 Advantages and Disadvantages Kirchhoff's Laws

- ***Advantages***

Kirchhoff's laws are applied to determine:

- The current, voltage, and internal resistance values in DC circuits.
- We may also use this law to find the unknown resistance in the circuit.
- Kirchhoff's laws are used extensively in the construction of Wheatstone Bridge. It's useful for mesh and node analysis.

- ***Disadvantages***

- Kirchhoff's laws are inapplicable to high-frequency alternating current circuits. Only when the electric charge in a circuit is constant does the current law apply.
- KVL is used under the assumption that magnetic fields in a closed circuit do not change. As a result, we cannot use KVL when the magnetic field fluctuates inside a circuit.

II.4. Electric circuits

The electric circuits are closed-loop or paths, forming a network of electrical components where electrons can flow. A simple circuit comprises the power source, conductors, switch, Passive elements and electrical wires. The start of the point from where the electrons start flowing is called the source, whereas the point where electrons leave the electrical circuit is called the return.

Passive elements include resistances, capacitors, and coils (also called inductors).

- What is the statement of Kirchhoff's first law?

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- Which is a correct statement of Kirchhoff's loop law?

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- What is the significance of Kirchhoff's first law?

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- Is Kirchhoff's first law applicable to AC circuits?

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What is the relationship between resistors R_i connected in series and their equivalent resistance R_{eq} :

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- What is the relationship between resistors R_i connected in parallels and their equivalent resistance R_{eq} :

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III. Tools and Materials

You have the following equipment:

- (01) DC voltage generator $E = ... V$,
- (01) Ammèter,
- (01) Voltmèter,
- two resistors. $R_1 = ...\Omega$ et $R_2 = ...\Omega$,.
- Unknown resistor
- Connector cable,
- breadboard

III.1 Etude expérimental

III.1.1 Mesure d'une résistance

- Carry out the electrical installation assembly:

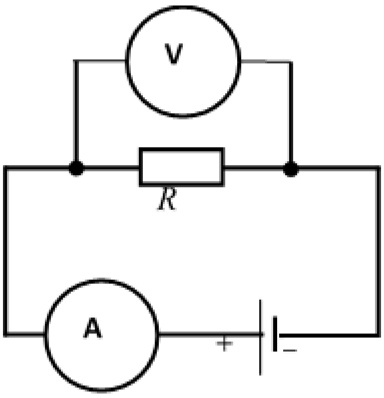

Figure 4 :*Diagram typical electric circuit.*

- Complete the following table:

Tension $U(V)$	1	2	3	4	5	6
Caliber of $U(V)$						
$\Delta U_{read}(V)$						
$\Delta U\ (V)$						
$\Delta U_{Tot}(V)$						
Current $I(A)$						
Caliber of $I(A)$						
$\Delta I_{Lect}(A)$						
$\Delta I_{App}(A)$						
$\Delta I_{Tot}(A)$						

- Draw the graph $U = f(I)$:

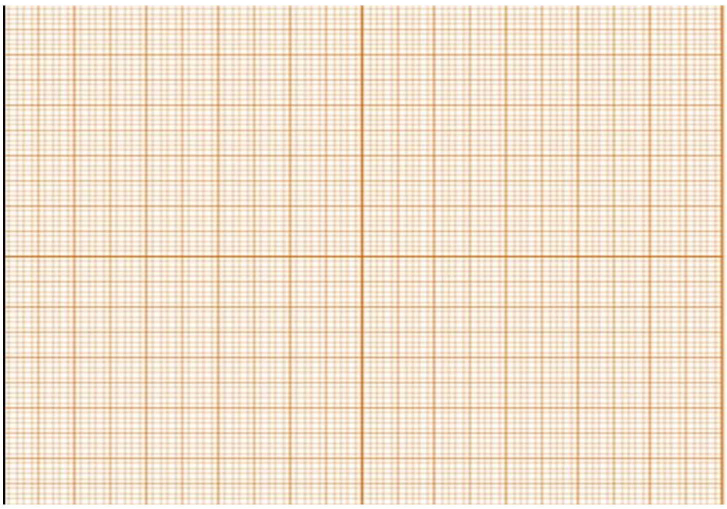

Figure 5 : *voltage-current characteristic of a resistor.*

- **Comment**

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Deduce the resistance values:

R_{max} = …………………, R_{min} = …………… , R_{moy} = ………………

ΔR = …………………………………

R = (……….… ± ……….……) Ω.

III.1.2 Verification of Kirchhoff's two laws

a_ Kirchhoff's Voltage law(KVL)

1°) Electrical assembly in series: assemble the resistors R_1 and R_2 in series according to the assembly opposite (Figure 3) by supplying the circuit with a DC voltage of $E = 6\,V$.

with : R_1 = …… Ω and R_2 = ……. Ω.

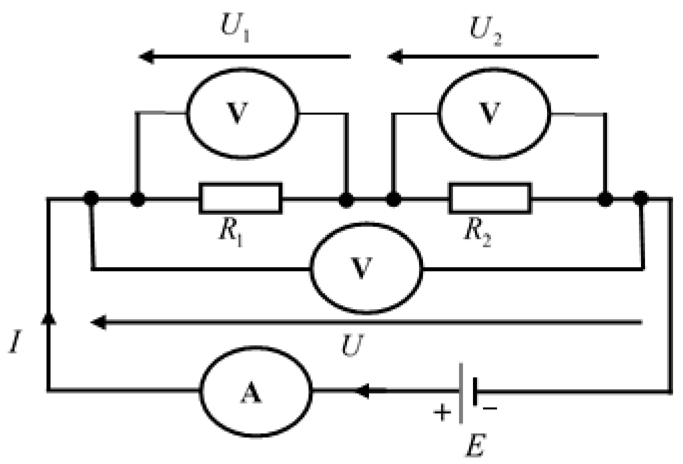

Figure 6: *electrical connection in series.*

- Measure the current intensity as well as the voltage values and complete the following table:

	Caliber	$\Delta X_{Appariel}$	$\Delta X_{Lecture}$	ΔX_{Totale}	Exact value of X
Current $I\ (mA)$					$I = (........\pm........)$
Tension $U\ (V)$					$U = (........\pm........)$
Tension $U_1\ (V)$					$U_1 = (........\pm........)$
Tension $U_2\ (V)$					$U_2 = (........\pm........)$
Tension $U_{Totale} = U_1 + U_2\ (V)$					$U_{Totale} = (........\pm........)$

- Compare this value with the measured value U :

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Deduce the equivalent resistance R_{eq} and ΔR_{eq} :

$R_{eq} = \frac{U}{I} = ...=........\ \Omega$ and $\Delta R_{eq} = ...$

$$R_{eq} = (.........\pm.........)\ \Omega$$

- Calculate the theoretical value of R_{eq} :

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- Compare these two values:

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b. Kirchhoff's current law

1°) Electrical assembly in parallel: mount the resistors R_1 and R_2 in parallel according to the assembly opposite (Figure 4) by supplying the circuit with a DC voltage of $E = 6\,V$. with : $R_1 = ...\ \Omega$ a $R_2 = ...\ \Omega$.

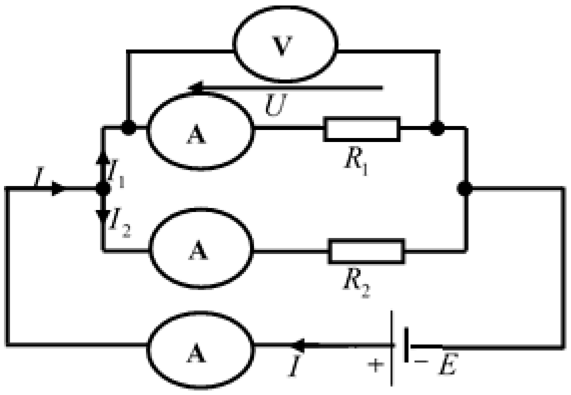

Figure 7 : *electrical connection in parallels.*

- Measure the current intensity as well as the voltage values and complete the following table:

	Caliber	$\Delta X_{Appariel}$	$\Delta X_{Lecture}$	ΔX_{Totale}	Exact value of X
Current $I\ (mA)$					$I = (........ \pm ....)$
Tension $U\ (V)$					$U = (........ \pm ....)$
Current $I_1\ (mA)$					$I_1 = (........ \pm ....)$
Current $I_2\ (mA)$					$I_2 = (........ \pm ....)$
Current $I_{Tot} = I_1 + I_2\ (mA)$					$I_{Tot} = (........ \pm ....)$

- Compare this value with the measured value I :

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.... Deduce the equivalent resistance R_{eq} and ΔR_{eq} :

$$R_{eq} = \frac{U}{I} = ...=........\ \Omega \quad \text{and} \quad \Delta R_{eq} = ...$$

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$$R_{eq} = (.........\pm.........)\ \Omega$$

- Calculate the theoretical value of R_{eq} :

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- Compare these two values:

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IV. Conclusions :

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Expriment 03

Thevenin's Theorem

Experiment N°3:

Thevenin's theorem

I.SPECIFIC OBJECTIVES

- *The aim of this experiment is to investigate the usage of Thévenin's Theorem to design simpler versions of DC circuits as an assistance to analysis. Multiple experimental strategies for obtaining Thévenin resistance will be investigated.*

II.Tools and Materials

You have the following equipment:

- Digital Multimeter,
- Electrical and Electronic System Trainer Kit or power supply,
- Resistor. (R1 = 5.1 kΩ, R2 = 8.6 kΩ, R3 = 6.5 kΩ, and R4 (R_{Load}) = 4 kΩ.
- Wire cutters,
- Connector cable,
- breadboard,
- Various connectors (banana plugs-to-alligator clips) for connecting the breadboard to Power supply

III.BASIC THEORY:

III.1 Thevenin's theorem

In electrical circuit theory, Any combination of voltage sources, current sources, and resistors with two terminals is electrically equivalent to a single voltage source V and a single series resistor R, according to Thevenin's theorem for linear electrical networks . The theorem applies not just to resistors but also to generic impedances for single frequency AC circuits. A Thevenin equivalent circuit, which consists of a single voltage source and series resistance coupled to a load, can be used to simplify any complex network.

III.2 How to Use Thevenin's Theorem

Thevenin’s theorem can make this analysis easy by temporarily removing the load resistance from the original circuit and reducing what’s left to an equivalent circuit composed of a single voltage source and series resistance.

After then, the load resistance may be connected back to the Thevenin equivalent circuit, and computations can be done as though the network were just a straightforward series circuit.

Step 1: First, eliminate the load resistance at the center of the circuit in order to analyze it using Thevenin's theorem.

Step 2: Remove the voltage sources’ internal resistance by shorting all the voltage sources connected to the circuit, i.e. circuit has current sources,

Step 3: Determine the resistance equivalent. The following formula is used in the example to determine the circuit's equivalent resistance:

With the load resistance removed and the voltage sources shorted, the equivalent resistance of the circuit is calculated as follows:

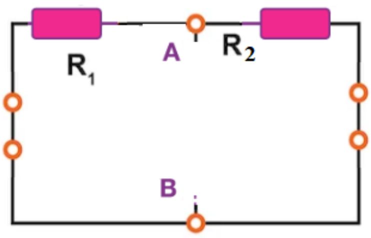

Figure 1:

La résistance équivalente vaut donc:

$$R_{Th} = \frac{R_1 R_2}{R_1 + R_2} \quad (3\text{-}1)$$

Step 4: Find the equivalent voltage.

To calculate the equivalent voltage, reconnect the voltage sources back into the circuit. $V_s = V_{AB}$, therefore the current flowing around the loop is calculated as follows:

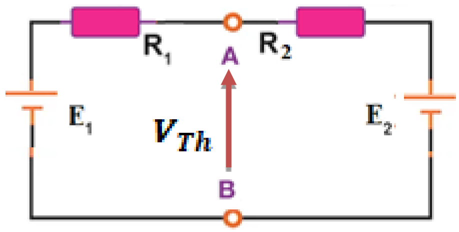

Figure 2:

$$I = \frac{E_2 - E_1}{R_1 + R_2} \quad (3\text{-}2)$$

The calculated current is common to both resistors, so the voltage drop across the resistors can be calculated as follows:

$$V_{Th} = V_{AB} = E_2 - IR_2 \quad (3\text{-}3)$$

Step 5: Draw the Thevenin's equivalent circuit. The Thevenin's equivalent circuit consists of a series resistance of R_{Th} and a voltage source of V_{Th}.

Our circuit in Figure 1 can be reduced to the Thevenin equivalent circuit in Figure 2 after the Thevenin conversion process.

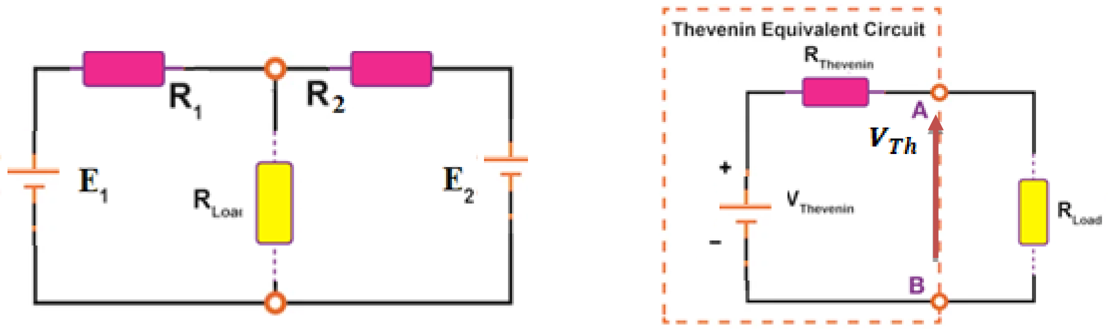

Figure 3:

III.3 Thevenin Theorem Applications

✓ Thevenin's Theorem is especially useful in analyzing power systems and other circuits where one particular resistor in the circuit (called the "load" resistor) is subject to change, and re-calculation of the circuit is necessary with each trial value of load resistance, to determine voltage across it and current through it.

✓ Source modeling and resistance measurement using the Wheatstone bridge provide applications for Thevenin's theorem.

IV. Manipulation 1

IV.1. Equipment Required

Breadboards, Voltage source, Ammeter, Voltmeter, Digital multimeter, three resistors

Consider the circuit in Figure 1 with E = 10 volts, R1 = 5.1 kΩ, R2 = 8.6 kΩ, R3 = 6.5 kΩ, and R4 (R_{Load}) = 4 kΩ.

This circuit can be examined using normal series-parallel approaches. Determine the voltage across the load, R4, and note it in Table 1. Repeat the procedure with 10 kΩ for R4.

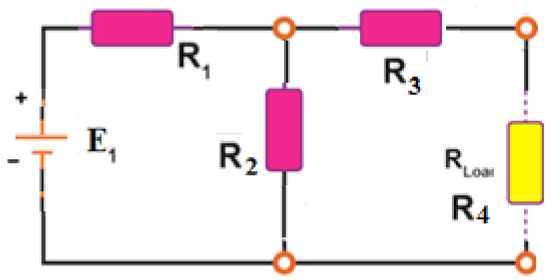

Figure 4:

Construct the circuit shown in Figure 4 using the values supplied in step one, with R_{Load} = 4 kΩ. Measure the load voltage and record it in Table 1 Rep with an 10 kΩ load resistance. Determine and document the deviations.

Table 1:

V_{Load} / Resistor	Theory	Experimental
R_{Load} = 4 kΩ		
R_{Load} = 10 kΩ		

Find the open circuit output voltage to determine the theoretical Thévenin voltage of the circuit shown in Figure 4. In other words, replace the load with an open and calculate the voltage produced between the two open terminals. Make a note of this voltage in Table 1.

The experimental Thévenin voltage can be calculated by measuring the open circuit output voltage. Simply remove the load from the first step's circuit and replace it with a voltmeter. This value should be recorded in the same Table 1 there are two ways for determining experimental Thévenin resistance. For the first way, utilizing the circuit from step one, replace the source with a short.

The ohmmeter is then used to replace the load. Thévenin resistance can now be measured directly. This value should be recorded in Table 2.

Ohmmeters are ineffective in powered circuits while power is applied. An alternative

way is to measure the effect of load resistance. Replace the short from step six by reconnecting the voltage source to the circuit. For the load, insert either the decade box or the potentiometer. Adjust this device

Table 2:

x	Theory	Experimental
E_{TH}		
RTH		

under "Method 2" Record the load voltage in Table 2 until it is half of the open circuit voltage measured in step five. As shown in Figure **5**, the load and Thévenin resistance form a simple series loop at this point. This implies that they both "see" the same current. If the load exhibits half of the Thévenin voltage, the other half must be dropped across the Thévenin resistance, so $V_{RL} = V_{RTH}$.

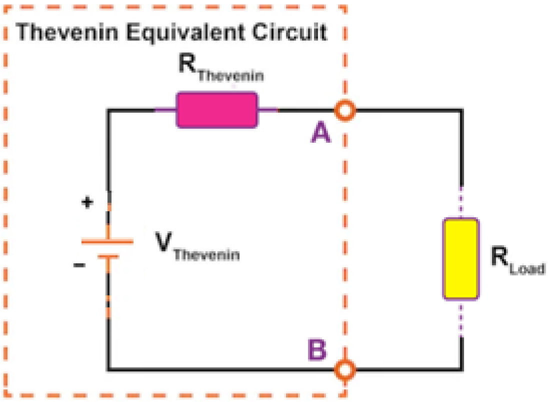

Figure 5:

Table 3:

V_{Load} / Resistor	Theory	Experimental
$R_{Load} = 4\ k\Omega$		
$R_{Load} = 10\ k\Omega$		

As a result, because the resistances have the same voltage and current, they must have the same resistance according to Ohm's law.

Consider the Thévenin equivalent of Figure 5 using the theoretical ETH and RTH from Table 3 along with 4 kΩ for the load (RL). Calculate the load voltage and record it in Table 3. Repeat the process for a 10 kΩ load.

Create the circuit shown in Figure 5 by utilizing the observed ETH and RTH from Table 3, as well as 4 kΩ for the load (RL). Calculate the load voltage and enter it into Table 4. Determine and note the deviation as well.

10. Repeat previous step using Rep with an 10 kΩ load resistance..

Table 4:

x	Theory	Experimental
E_{TH}		
RTH		

V. Conclusions

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Experiment 4

Capacitors, Inductors and their assemblies

Experiment N°4:

Capacitors, Inductors and their assemblies

I. SPECIFIC OBJECTIVES

- ✓ *The objective of this experiment is to measure the equivalent capacitance of two capacitors connected in series and parallel. First the individual capacitances and their equivalent will be measured. you can do the same work for the inductors*

- ✓ *Then we will charge the capacitors by connecting the combination to a battery and then measuring the voltage across each capacitor. This will allow us to calculate the charge on the capacitors and then calculate the equivalent capacitance using the equation C = Q/V.*

II. BASIC THEORY

II.1 Inductor

II.1.1 What is an Inductor?

An inductor is a passive electronic component that temporarily stores energy in a magnetic field, which, as an AC resistance, produces a counter-voltage, the self-induction voltage.

when electric current flows through the inductor's coil. In its simplest form, an inductor consists of two terminals and an insulated wire coil that either loops around the air or surrounds a core material that enhances the magnetic field. Inductors help to handle fluctuations in an electric current running through a circuit.

When current passes through an inductor, it generates a magnetic field around the coil. The strength of this magnetic field is directly proportional to the current passing through it. One of the fundamental properties of an inductor is its inductance, measured in henrys (H), which signifies the ability to store energy in the magnetic field.

An inductor resists changes in the current passing through it. When the current flowing through an inductor changes, it induces a voltage across its terminals according to Faraday's law of electromagnetic induction. This voltage opposes the change in current, resulting in the inductor's property known as self-inductance.

The self-induction voltage (U_{ind}) at the terminals of the inductor is dependent on the rate of current change (di/dt) and a constant of proportionality, the inductance (L):

$$U_{Ind} = -L\frac{di}{dt} \tag{4-1}$$

The inductance (L) of the coil is dependent on the core material, the geometry of the core material, the winding turns and the type of windings. The following equation applies generally for calculating an inductance (L):

The unit of **inductance (L) is the Henry (H) = Vs/A**

- Inductive reactance

As the frequency of the sine wave increases, the rate of change of the current also increases, and so the induced (reacting) voltage across the inductor increases. As a result, the net current through the inductor decreases. That means, the inductor's reactance increases with frequency.The inductive reactance is given by :

$$X_L = 2\pi f L \tag{4-2}$$

As with capacitors and resistors, Ohm's law can be applied to inductive circuits:

$$X_L = \frac{V_L}{I_L} \tag{4-3}$$

II.1.2 Basic Structure of Inductors and Inductance

The most basic inductors consist of a conductive wire wound in a coil shape, with both ends of the conductive wire as external terminals. In recent years, most inductors include a core, around which a conductive wire is wound.

Figure 1: *basic structure of an inductor (left) and its practical examples (right)*

II.1.3 Inductor Applications

Inductors are primarily used in electrical power and electronic devices for these major purposes:

1. Choking, blocking, attenuating, or filtering/smoothing high frequency noise in electrical circuits
2. Storing and transferring energy in power converters (dc-dc or ac-dc)
3. Creating tuned oscillators or LC (inductor / capacitor) “tank” circuits

II.2 Capacitor

II.2.1 What is a Capacitor?

Capacitors are electronic components that can be used to store electrical charges within a certain time. Capacitors are generally made of two pieces of the conductor plate inserted down the middle slab called the dielectric insulator. If a capacitor is connected with the direct current source in a while, there will be an electric current which flows into the capacitor, the condition is called a capacitor charging process, if the electric charge on the capacitor is full, the flow of electric current stops.Capacitance of a capacitor is defined as the ability of a capacitor to store the maximum electrical charge (Q) in its body. Here the charge is stored in the form of electrostatic energy.

A capacitor is a two-terminal electrical device that can store energy in the form of an electric charge. It consists of two electrical conductors that are separated by à distance. The space between the conductors may be filled by vacuum or with an insulating material known as a dielectric. The ability of the capacitor to store charges is known as capacitance.

Capacitors store energy by holding apart pairs of opposite charges. The simplest design for a capacitor is a parallel plate, which consists of two metal plates with a gap between them. But, different types of capacitors are manufactured in many forms, styles, lengths, girths, and materials.

II.2.2 The Capacitance of a Capacitor

Capacitance is an electrical attribute of a capacitor that measures its ability to store an electrical charge on its two plates. The Farad (abbreviated to F) is the unit of capacitance.

Capacitance is defined as the capacitance of a capacitor when a charge of one coulomb is stored on the plates by a voltage of one volt. It is important to note that capacitance, C, is always positive in value and has no negative units. However, the Farad is a very large unit of measurement to use on its own so sub-multiples of the Farad are generally used such as micro-farads, nano-farads and pico-farads, for example.

The capacitance is measured in the basic SI units i.e. Farads. These units may be in micro-farads, nano-farads, pico-farads or in farads. The expression for the capacitance is given by :

$$C = \frac{Q}{V} \tag{4-4}$$

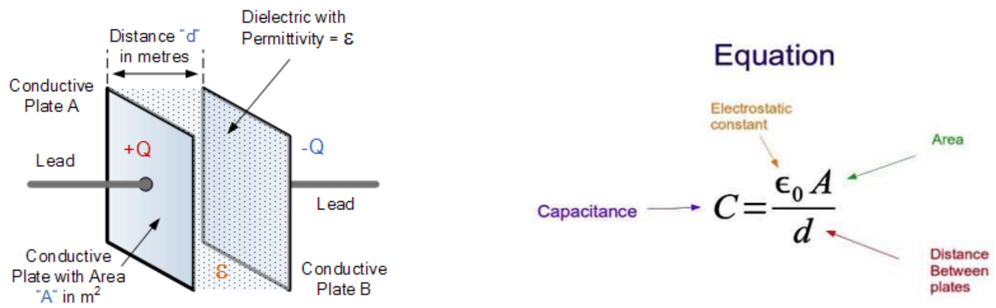

Figure 2 : *parallel Plate Capacitor*

In the above equation C is the capacitance, Q is the charge and V is the potential difference between the plates,

$$C = \frac{\varepsilon \times A}{d} = \frac{\varepsilon_0 \varepsilon_r \times A}{d} \qquad (4\text{-}5)$$

A is the area between the plates, d is the distance between the plates.

ε permittivity of dielectric

ε_0 permittivity free space

ε_r relative permittivity of free space

II.2.3 Discussion 1

A real capacitor formed by the parallel association of a perfect capacitor (capacitance C) and a resistor R_l called the leakage resistor.

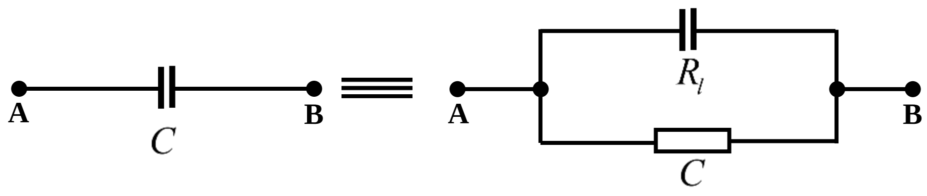

Figure 3 : e*quivalent circuit of capacitance* C .

III. Manipulation 1

III.1. Equipment Required

Breadboards, Voltage source , frequency generator, Ammeter, Voltmeter , Two capacities $C_1 = ... \mu F$ et $C_2 = ... \mu F$, and connecting wires (leads).

III.2. Experimental procedure

1. Make sure that each capacitor is discharged (V=0) by connecting a wire lead across the capacitor for about 30 seconds.
2. Make sure the ends of the lead wires do not come in contact with each other.

III.3. Calculate of the leakage resistor R_l :

An ideal capacitor only stores and releases electrical energy, without dissipation. In practice, all capacitors have imperfections within the capacitor's materials that permit leakage current, and represent resistance. This is specified as the equivalent series resistance (ESR) of the device. It adds a real-valued component of the impedance: As frequency approaches infinity, the capacitive impedance (reactance) approaches zero and the ESR becomes significant.

$$Y_c = Y + R_{ESR} = \frac{1}{jwC} + R_{ESR} \quad (4\text{-}6)$$

.Measure I and V ; and deduce $R_l = V/I$.

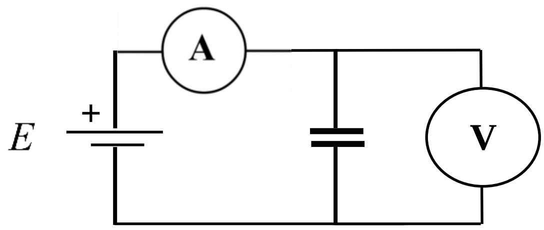

Figure 4: *Electrical assembly powered by a DC voltage source*

**Nb : ** we will see that this resistor is very large, the measured current being very low.

III.4. Calculate the capacity C :

a°) The circuit is supplied by an alternating voltage source of frequency 1 KHz. The devices are in alternate position.

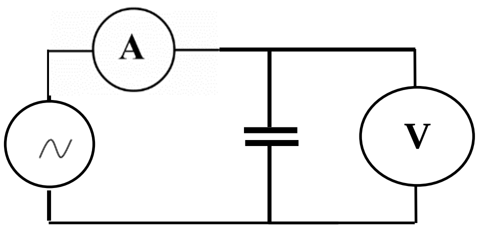

Figure 5 : *Electrical assembly powered by a AC voltage source*

b°) Draw the following table:

Tension V (Volt)	1	2	3	4	5	6
Current I (mA)						

Knowing that the expression of the impedance $Y = I/V$ *of the circuit* $R_l C$ *is parallel :*

$$Y = \sqrt{\frac{1}{(R_f)^2} + (C\omega)^2} \qquad (4\text{-}7)$$

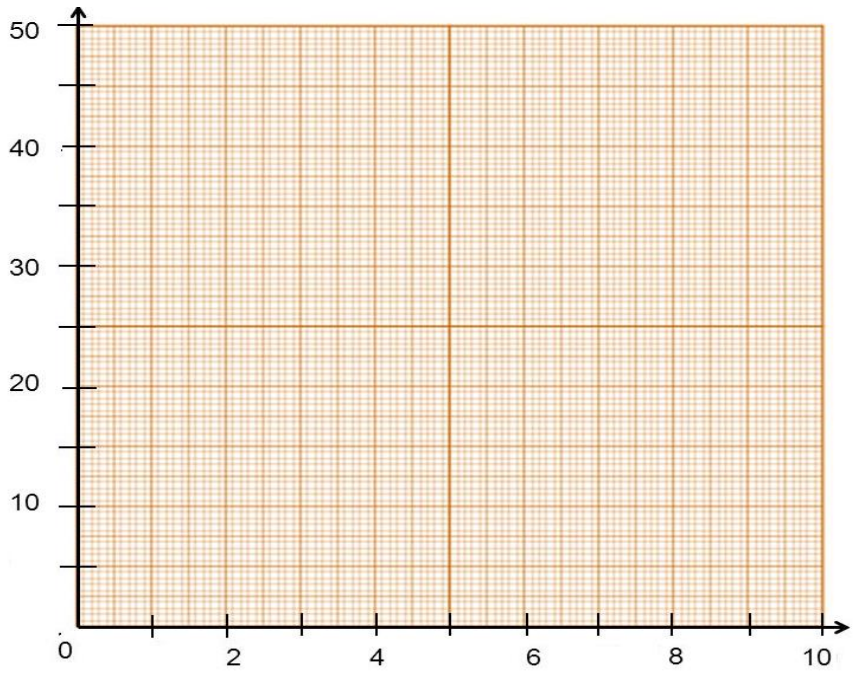

Figure 6 : *variation of current as a function of voltage* $I = f(V)$.

we calculate the capacity

$$C = \frac{1}{\omega}\sqrt{\left(\frac{I}{V}\right)^2 - \left(\frac{1}{R_f}\right)^2}. \qquad (4\text{-}8)$$

Take the various measurements of I for a well-defined range of the applied voltage, plot the curve $I = f(V)$, (make these measurements with C_1) and deduce the value of C_1.

Calculation of the value of C_1:

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c°) Replace C_1 by C_2 and apply a voltage $V = 1{,}5\,Volt$, measure the magnitude I and deduce the value of capacitor C_2.

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d°) Compare the results found from C_1 and C_2 with their industrial values and comment.

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IV. Discussion 2:

IV.1 Capacitors

IV.1.1 Serie Capacitors

In a series capacitive circuit, the same displacement current flows through each part of the circuit and the applied voltage will divide across the individual capacitors. The figure below shows a circuit containing a source and three series capacitors.

When capacitors are connected one after another, they are said to be in the series. For capacitors in series, the total capacitance can be found by adding the reciprocals of the individual capacitances, and taking the reciprocal of the sum.

The charges on all capacitors must be the same, since the capacitors are connected in series and any charge movement in one part of the circuit must take place in all parts of the series circuit.

$$Q_T = Q_1 = Q_2 \tag{4-9}$$

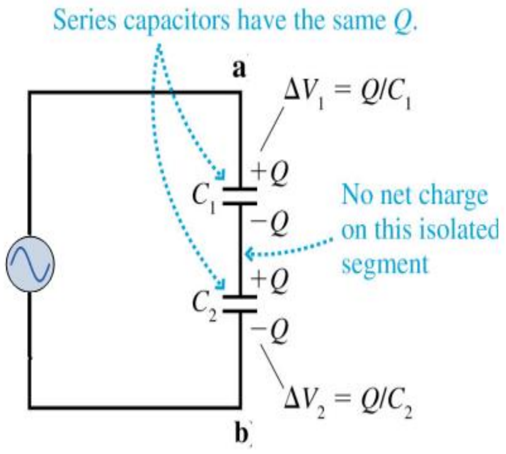

Figure 7 : *Capacitor in Series*

The total capacitance for a series combination of capacitors is given by

$$\frac{1}{C_{Tp}} = \frac{1}{C_1} + \frac{1}{C_2} \Rightarrow C_{Tp} = \frac{C_1 . C_2}{C_1 + C_2} \quad (4\text{-}10)$$

On calcule la capacité d'un condensateur équivalent C_{eq} à deux condensateurs C_1 et C_2 monté en parallèle par la relation suivante:

$$C_{eq} = C_1 + C_2 . \quad (4\text{-}11)$$

IV.1.2 Parallel Capacitors

A parallel circuit is the most convenient way to increase the total storage of electric charge.

In the following circuit the capacitors, C_1 and C_2 are all connected together in a parallel branch between points A and B as shown.

The total voltage rating does not change. Every capacitor will 'see' the same voltage. They all must be rated for at least the voltage of your power supply.

We can define the total capacitance of the parallel circuit from the total stored coulomb charge using the equation Q = CV for charge on a capacitors plates.

The total charge Q_T stored on all the plates equals the sum of the individual stored charges on each capacitor therefore,

$$Q_T = Q_1 + Q_2 \quad (4\text{-}12)$$

we can also define the total or equivalent circuit capacitance, C_T as being the sum of all the individual capacitance's add together giving us the generalized equation of:

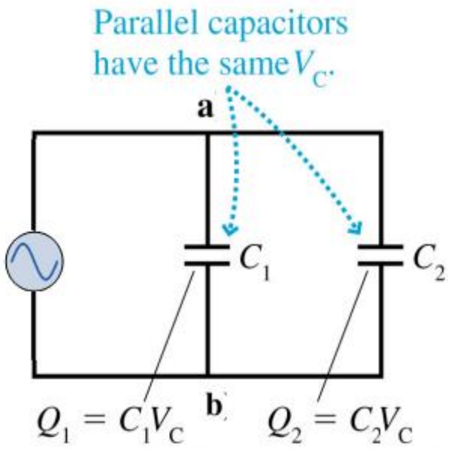

Figure 8 : *Capacitor in Parallel*

$$C_{Tp} = C_1 + C_2 \tag{4-13}$$

V. Manipulation 2

Wire the capacitors in series as shown in Figure.7 (but do not connect them to the battery). Pay close attention to the polarity of the capacitors and the way they are connected. The capacitors used in this experiment are electrolytic capacitors and the polarity of the plates is important. Make sure the ends of the lead wires do not come in contact with each other.

We use the same assembly of figure 7 with a capacity of a capacitor equivalent to two capacitors C_1 and C_2 in series and apply a voltage $V = 1{,}5\ Volt$ and measure the intensity of the current I .

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What is the total capacitance when two capacitors, C1 and C2, are connected in a series?
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We repeat the same manipulation but with a parallel assembly of capacitors C_1 and C_2.
Apply a voltage $V = 1{,}5\,Volt$ and measure the intensity of the current I.
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Deduce the equivalent capacitance C_{eq} when two capacitors C_1 and C_2 connected in parallel:

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a°) Prove mathematically the two relations already given capacitor

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VI . Discussion 2:

VI.1 Inductors

Inductors are passive electronic components that store energy in a magnetic field when current flows through them. They are commonly used in electronic circuits for various purposes, such
as filtering, energy storage, and inductance.

VI.1.1 Serie Inductors

When inductors are connected in series, their total inductance is the sum of the individual inductances. The current passing through each inductor is the same because they share a common current path. The total inductance (L_{total}) of inductors in series is calculated as follows:

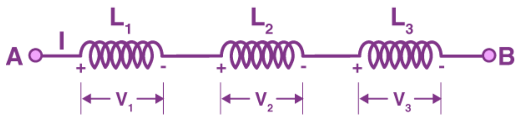

Figure 9: *Inductor in Series*

$$L_T = L_1 + L_2 + L_3 \quad (4\text{-}14)$$

Here, L_1,L_2,L_3 are the individual inductances.

The equivalent inductance of inductors in series is greater than the individual inductances. The formula can be extended to any number of inductors in series.

6.1.1 Parallel Inductors

When inductors are connected in parallel, the reciprocal of the total inductance is the sum of the reciprocals of the individual inductances. The voltage across each inductor is the same because they share a common voltage.

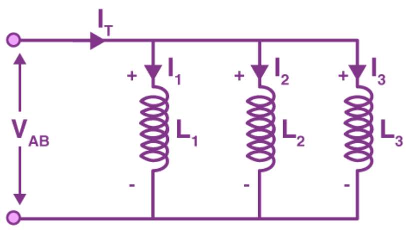

Figure 10: *inductor in parallel*

The formula for the total inductance (L_{total}) of inductors in parallel is given by:

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} \quad (4\text{-}15)$$

Here; $L1$,$L2$,$L3$ are the individual inductances.

The equivalent inductance of inductors in parallel is always less than the smallest individual inductance. Adding more inductors in parallel reduces the overall inductance.

These formulas are useful in analyzing and designing circuits that involve inductors. Understanding how inductors behave in series and parallel configurations is essential for proper circuit design and analysis.

VII. Manipulation 3

- Connect the circuit as shown in Figure 11.

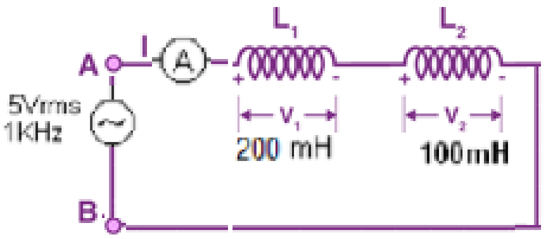

Figure 11: *Inductor in Series in exp*

1. Measure the currents and the voltages I_{L1}, I_{L2}, V_{L1}, V_{L2} and V_{Ltot}.
2. Calculate (from the measured values) X_{L1}, X_{L2}, X_{Ltot} then L_1, L_2 and L_{tot} and subsequently,
3. Compare between the measured and calculated value for L_{tot}.

- We repeat the same manipulation but with a parallel assembly of inductors L_1 and L_2 as shown in Fig.12,

1. Measure the currents and the voltages I_{L1}, I_{L2}, I_{Ltot}, V_{L1}, V_{L2} and V_{Ltot}.
2. Calculate (from the measured values) X_{L1}, X_{L2}, X_{Ltot} then L_1, L_2 and L_{tot} and subsequently
3. Compare between the measured and calculated value for L_{tot}.

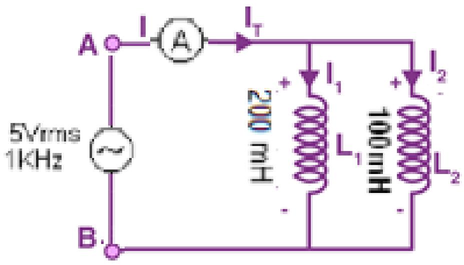

Figure 12: *Inductor in parallels in exp*

VIII. Conclusion

What can you deduce from the two manipulations, justify your answer

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Experiment 5

Capacitor Charging and Discharging

Experiment N° 5:

Capacitor Charging and Discharging

I. SPECIFIC OBJECTIVES

- *In this experiment, we will aim to learn about the following concepts:*
- *Understand the working principle of the Capacitors,*
- *The objective of this experiment is the study of charging and discharging of a capacitor by measuring the potential difference (voltage) across the capacitor as a function of time,*
- *Determine the value of RC time constant calculation,*

.

II. Tools and Materials

You have the following equipment:

1. (01) DC voltage générator $E = ... V$,
2. (01) switch,
3. (01) Condensateur,
4. (01) Multimèter,
5. Two known resistances. $R_{Ch} = \cdots$ et $R_{Dech} = \cdots$.
6. Connector cable,
7. breadboard,

Be warned that most large capacitors are of the electrolytic type, and they are polarity sensitive! One terminal of each capacitor should be marked with a definite polarity sign (+ or -). Usually, capacitors of the size specified have a negative (-) marking or series of negative markings pointing toward the negative terminal. Very large capacitors are often polarity-labeled by a positive (+) marking next to one terminal.

(01) (02) (03) (04) (05) (06) (07)

III. BASIC THEORY

III.1 Capacitors

Capacitance is the storing ability of a capacitor, which is measured in Farad**.** Capacitors are frequently used to store electrical energy and release it when needed. Capacitors, when combined with other circuit components, form a filter that permits some electrical impulses to pass while blocking others. Many modern devices, such as pacemakers, mobile phones, or computers, use capacitors as key components of electrical circuits.

Capacitance is the measured value of the ability of a capacitor to store an electric charge. Then, a capacitor has the capacity to store an electrical charge Q (measured in Coulombs). The greater the area of the plates and/or the smaller the space between them (known as separation) the greater the charge that the capacitor can carry and the greater the capacitance. A capacitor has a potential difference (p.d.) between its plates when it is completely charged.

All capacitors have a maximum voltage rating and when selecting a capacitor consideration must be given to the amount of voltage to be applied across the capacitor. The maximum amount of voltage that can be applied to the capacitor without damage to its dielectric material is generally given in the data sheets as: WV, (DC working voltage).voltage) or as WV DC, (DC working voltage).

A capacitor has a potential difference (p.d.) between its plates when it is completely charged.

A typical capacitor takes the form of two conductive plates separated by an insulator (dielectric). This type of circuit element cannot pass direct current (DC) because electrons cannot flow through the dielectric. However, a capacitor does pass alternating current (AC) because an alternating voltage causes the capacitor to repeatedly charge and discharge, storing and releasing energy. Indeed, one of the major uses of capacitors is to pass alternating current while blocking direct current, a function called 'AC coupling'. ge rapidly builds up on the positive plate and a corresponding negative charge fills the negative

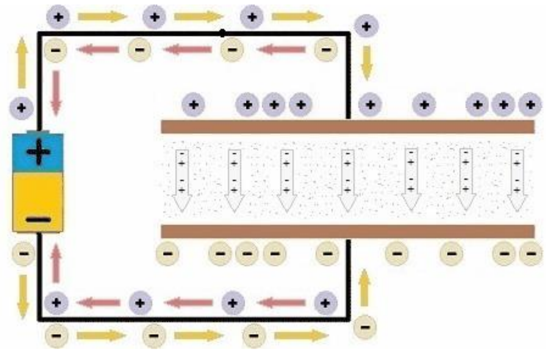


Figure 1: *RC Charging Circuit.*

When a direct current flows into a capacitor, a positive char plate. The buildup continues until the capacitor is fully charged—i.e., when the plates have accumulated as much charge (Q) as they can hold. This amount is determined by the capacitance value (C) and the voltage applied across the component: (Q = CV). At that point, current stops flowing (see Figure 1).

III.2 Charge and discharge of Capacitors

It is necessary to learn what happens when a capacitor charges and discharges. Capacitors are extremely important in electronic timing circuits due to their ability to control and predict the rate at which they charge and discharge (Figure.2).

When you move the switch to position 1, you will see that the Multimeter changes quickly. Indeed, there is a movement of electrons when the switch is moved to position 1.

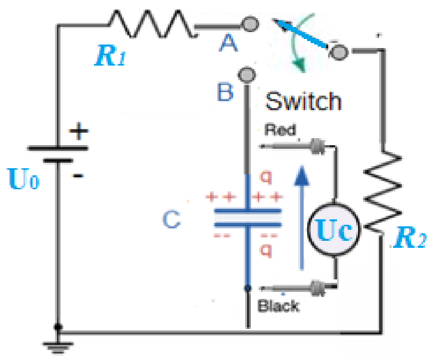


Figure .2. *RC Charging Circuit.*

Through the strength of the electric field, the positive pole of the DC power supply attracts electrons into the upper conductive plate while the negative pole pushes electrons towards the lower conductive plate.

The top plate charges positively, having lost electrons, while the bottom plate charges negatively, having gained electrons. There is now a potential difference between the two plates of the capacitor, which is in the opposite direction of the DC potential. So, how do the values read by the Multimeter evolve?

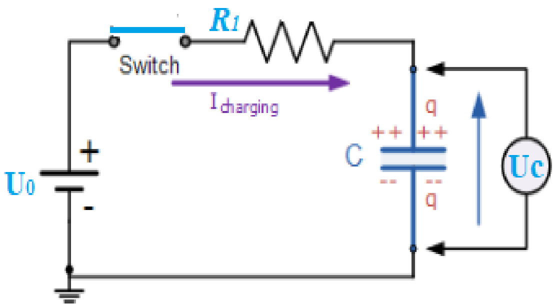


Figure .3 : *RC Charging Circuit.*

When the switch is in position 1 as shown in Figure.3, charge on the conductors builds to a maximum value after some time.

According to kirchhoff's law, we show that :

$$U_c(t) = U_0\left(1 - e^{\frac{-t}{\tau}}\right) \quad (5\text{-}1)$$

and

$$I_c(t) = I_0 e^{\frac{-t}{\tau}} \quad (5\text{-}2)$$

When the switch is thrown into position 2 as in Figure.4, the battery is no longer part of the circuit and, therefore, the charge on the capacitor cannot be replenished. As a result, the capacitor discharges through the resistor. If we wish to examine the charging and discharging of the capacitor, we are interested in what happens immediately after the switch is moved to position 1 or position 2, not the later behavior of the circuit in its steady state.

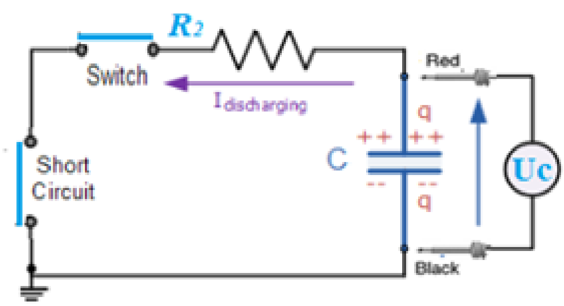


Figure. 4: *RC Discharging Circuit.*

When the switch is set to position 2, no voltage is applied to the capacitor, and so no electric field exists. Electrons in conductive plates are immobile, and the plates do not charge positively or negatively. As a result, the potential difference between them is zero, and the voltmeter displays 0.

As for the load case, we show that :

$$\boldsymbol{U_C(t) = U_0 e^{\frac{-t}{\tau}}} \quad (5\text{-}3)$$

et

$$\boldsymbol{I_C(t) = I_0 e^{\frac{-t}{\tau}}} \quad (5\text{-}4)$$

III.3 Time constant

The product RC has a special significance; it is called the time constant of the circuit. The time constant of a discharging capacitor is the time taken for the current, charge or Potential difference to decrease to 37% $(e^{-1} = 0.368)$ of the original amount. It can also be calculated for a charging capacitor to reach 63 % $(1 - e^{-1} = 0.632)$ of its maximum charge or potential difference.

The time constant (τ) of a resistor-capacitor circuit is calculated by taking the circuit resistance, R, and multiplying it by the circuit capacitance, C.

$$\tau = RC \quad (5\text{-}5)$$

τ is the time constant in seconds (s)

R is the resistance of the resistor connected to the capacitor in ohms Ω

C is the capacitance in the capacitor (F).

IV. Etude expérimental

IV.1 Study of the charge of a capacitor

Wire up the circuit (a resistor and a capacitor are connected in series with a battery and a switch) shown in Figure 3, but have your lab instructor check your circuit before closing the switch. For the switch you will use one side of a double-throw switch. The resistance $\boldsymbol{R_1}$ is at ……kΩ. Use the capacitor withthe larger capacitance labeled on………..

It is important that the capacitor isconnected with its ⊕ terminal to the ⊕ side of the battery/

voltage supply.Connect the voltmeter directly to the power supply and verify that the voltage remains constant E=12V.If not, make the necessary changes. Make sure the capacitor is completely discharged.Short it with a wire to completely discharge it.

A capacitor Cischarged through a resistance $\boldsymbol{R_1}$ by putting switch S in position (A) of circuit shown in figure 3. Start the stopwatch and turn the switch on simultaneously. For every 5 seconds, you should read the voltage as accurately as possible for the first minute then every 10 seconds for the second minute and finally every 20 seconds for the third minutes – it will increase quite quickly at first.

Complete the following measurement table:

t(s)	0	5	10	15	20
U_c (Volts)					

25	30	35	40	45	50

55	60	70	80	90	1OO

120	140	160	180	200	240

. Plot a graph between voltage and time for charging capacitor on the millimeter sheet .

IV.2 Study of the discharge of a capacitor

Now remove the battery and wire up the circuit (a resistor and a capacitor are connected in series with a switch) shown in Figure 4. For the switch you will use one side of a double-throw switch. The resistance $\boldsymbol{R_2}$ is set on a variable decade resistance box and should be set at ……kΩ. Use the same capacitor with capacitance labeled on……….. It is important that the capacitor is connected with its ⊕ terminal to the ⊕side of the battery/voltage supply.

A capacitor C is discharged through a resistance by putting switch S in position (B) of circuit shown in figure 4. Start the stopwatch and R_2 turn the switch on simultaneously.

For every 5 seconds, you should read the voltage as accurately as possible for the first minute then every 10 seconds for the second minute and finally every 20 seconds for the third minutes – it will increase quite quickly at first.

- Complete the following measurement table :

t(s)	0	5	10	15	20
U_c *(Volts)*					

25	30	35	40	45	50

55	60	70	80	90	1OO

120	140	160	180	200	240

- Plot a graph between voltage and time for discharging capacitor on the millimeter sheet.

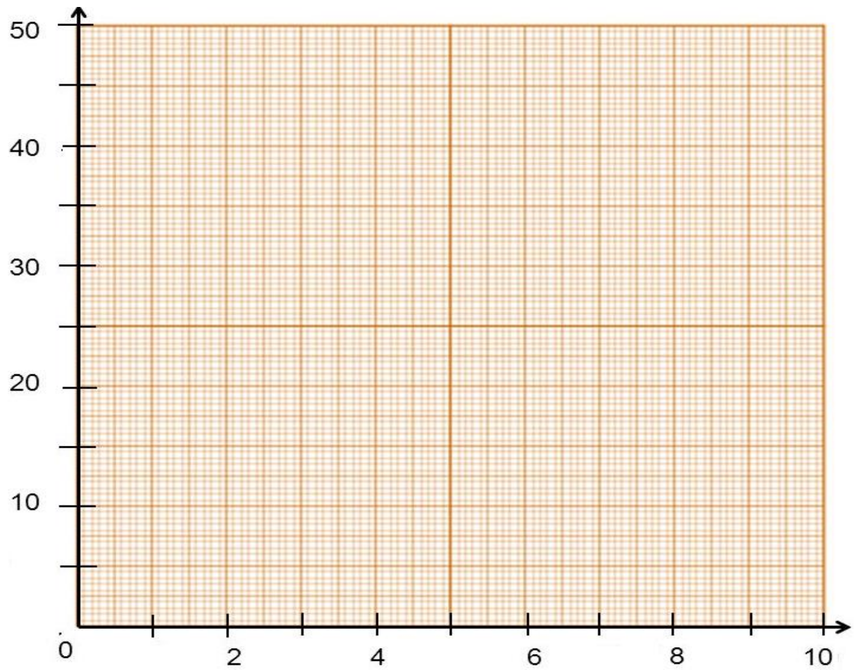
The time constant for this circuit is the time taken for the charge stored to increase from 0 to 63% of its final value. Use the graph to find the time constant in milliseconds.

From the parameters in the formula for the fitted curve and the known resistance, you can now calculate the capacitance *C*.

A capacitance C capacitor discharges through a resistance R resistor.

- Which of the following assertions is false? justify your answer

A. If R is increased, the time constant will grow



B. If C is increased, the time constant will decrease.

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V. Conclusion

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Experiment 06

Oscilloscope

Experiment N°6:

Oscilloscope

I. SPECIFIC OBJECTIVES

- *The objective of this lab is to introduce students to the fundamental tools used by engineers and technicians in the analysis of electronic equipment: the function generator, analog oscilloscope, and digital oscilloscope.*

II.Tools and Materials

You have the following equipment:

- Oscilloscope,
- Function Generator,
- Wire cutters**,**
- Connector cable,
- breadboard,
- Various connectors (banana plugs-to-alligator clips) for connecting the breadboard to the power source and connecting the multimeter,

III.BASIC THEORY:

III.1 Oscilloscope

An oscilloscope is a type of electrical test tool that shows and analyzes signals graphically. It shows the voltage versus time waveform of a signal, allowing you to watch and analyse the behavior of electrical systems. An oscilloscope is a tool that is extensively used in the fields of electronics, telecommunications, and computer engineering to diagnose, debug, and develop systems.

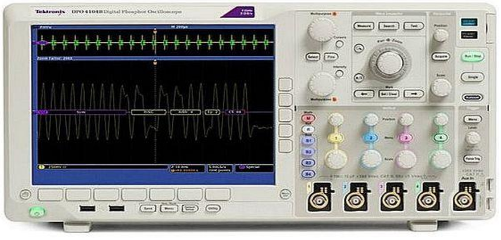


Figure 1: *An oscilloscope*

There are two types of oscilloscopes: analog and digital. For a long period, the analog oscilloscope was the workhorse tool in scientific laboratories. Because of advancements in integrated circuit technology, newer digital oscilloscopes are increasingly being used in these facilities.

III.2 Block Diagram of Cathode Ray Oscilloscope

The analogue oscilloscope has a large number of circuit blocks and is able to provide stable images of incoming waveforms. The analogue scope was in use for many years and its circuitry was well tried and tested.

As seen in the diagram above, a CRO employs a cathode ray tube (CRT), which serves as the oscilloscope's heart.

The CRT of an oscilloscope creates electron beams that are accelerated to high speeds and brought into focus on a fluorescent screen. Where the electron beam strikes this screen, a visible spot appears. The electrons can be made to operate as an electrical pencil of light, producing a spot of light wherever it strikes, by deflecting the beam over the screen in response to the electrical signal.

Various electrical signals and voltages are required to complete these duties, which are supplied by the oscilloscope's power supply circuit.

The heater of the electron cannon requires a low voltage source to generate the electron beam, whereas the cathode ray tube requires a high voltage supply to accelerate the beam. Other oscilloscope control units require a standard voltage supply.

Horizontal and vertical deflection plates are installed between the electron cannon and the screen to deflect the beam based on the input signal.

To deflect the electron beam on the screen in horizontal direction i.e. X-axis with constant time dependent rate, a time base generator is provided in the oscilloscope.

The signal to be viewed is sent into the vertical deflection plate via the vertical amplifier, which amplifies the signal to a level that provides useful electron beam deflection. Because the electron beam is deflected in both the X and Y axes, a triggering circuit is provided to synchronize these two types of deflections so that horizontal deflection always begins at the same position in the input vertical signal.

To deflect the electron beam on the screen in horizontal direction i.e. X-axis with the constant time dependent rate, a time base generator is provided in the oscilloscope.
The signal to be viewed is supplied to the vertical deflection plate through the vertical amplifier, so that it can amplify the signal to a level that will provide usable deflection of the electron beam.
As the electron beam is deflected in X-axis as well as Y-axis, a triggering circuit is provided for synchronizing these two types of deflections so that horizontal deflection starts at the same point of the input vertical signal each time it sweeps.
Since CRT is the heart of the oscilloscope, we are going to discuss its various components in detail.

A general-purpose oscilloscope consists of the following parts:

1. Glass Envelope
2. Fluorescent Screen for CRT
3. Deflecting Plate
4. Electronic Gun

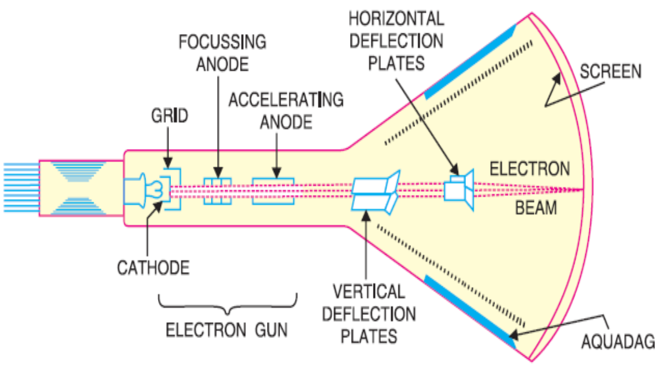


Figure 2: *Block Diagram of CRO (Cathode Ray Oscilloscope)*

1-Electronic Gun

The main function of an electron gun is to generate the electrons to form them into a ray. This primary function of an electron gun is to create electrons in order to form a ray.

A heater, a grid, a cathode, a focusing anode, an accelerating anode, and a pre-accelerating anode can all be added to this gun.

Strontium and barium layers can be placed on the cathode end to achieve strong electron emission at room temperature.

After the electrons are discharged from the cathode grid, they supply the control grid, which is typically a nickel cylinder, via a centrally positioned co-axial and the CRT axis. It regulates the intensity of the discharged electrons from the cathode.

A strong positive potential can be accelerated by an electron flowing through the control grid. This potential can be given to the accelerating or pre-accelerating nodes..

The electron ray is focused on electrodes & supplies throughout the two deflection plates & goes finally on to the fluorescent lamp. Both the anodes like accelerating and pre-accelerating are connected to 1500 volts whereas the focusing electrode can be connected to 500volts

On the electron ray-like, there are two focusing methods: electrostatic and electromagnetic. An electrostatic focusing tube is used in the cathode-ray oscilloscope.

2-Deflecting Plate

When the electron beam leaves the electron gun, it travels via the two pairs of deflecting plates. A Y plate or vertical deflecting plate is a pair of plates that emits vertical deflection. An X plate or horizontal deflection plate is a pair of plates that is mostly used for horizontal deflection.

3-Fluorescent Screen for CRT

The primary function of phosphor is to convert electrical energy to light energy. When an electrical ray strikes a phosphor crystal, its energy level rises, allowing light to be produced throughout the crystallization of phosphorous, a phenomenon known as fluorescence..

4-Glass Envelope

The Glass envelope has the shape of an empty conical shape. The interior CRT surface between the display and the neck is covered with a conducting substance such as aquadag. This material functions as a high-voltage electrode. The covering surface is electrically connected to the anode, allowing the electron to be the center of attention.

III.3 Operation of Cathode Ray Oscilloscope

Once the electron ray is injected through the electron gun, the cathode ray oscilloscope is supplies using the control grid so that the electron intensity within the vacuum tube can be regulated. If this grid has a large negative potential, it only allows a few electrons to flow across it. As a result, a dim spot appears on the lightning display.

On the control grid, the negative potential is less, allowing for the generation of a bright spot. As a result, the light intensity is depends by the negative potential of the control grid. When the control grid is shifted, electron beams supply the accelerating and focusing anodes. These anodes have a strong positive potential and come into contact with the ray at a specified spot on the display.

When the grid travels away from the accelerating anode, the ray passes beneath the effect of the deflecting plate. When this plate has no potential, the ray will generate a dot in the center. If a voltage is provided to the vertical deflecting plate, the electron ray will focus upward. Similarly, if the voltage is applied horizontally,

There are four major control groups on the oscilloscope; Each group serves a distinct purpose in controlling different aspects of the oscilloscope's functionality.

i. ***Display Group***: This group usually includes controls for brightness, intensity, focus, and other settings related to how the waveform is visually displayed on the screen. It allows adjustments for better visibility and clarity of the signal.

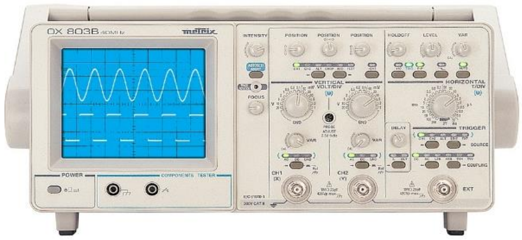
ii. ***Vertical Group***: Controls within this group manage the vertical positioning, scaling, and sensitivity of the signal displayed on the oscilloscope screen. It enables users to adjust the amplitude and voltage of the waveform being observed.

iii. ***Horizontal Group***: This group deals with controlling the time base, horizontal positioning, and scaling of the waveform on the screen. It allows users to adjust the time and frequency aspects of the displayed signal.

iv. ***Trigger Group***: The trigger function is crucial in synchronizing the waveform display. This group contains controls related to triggering, such as trigger level, trigger source, trigger type, and triggering mode. It ensures stability and consistency in displaying repetitive waveforms.

III.3.1 Display Group

The display group is responsible for displaying and adjusting the signal for best viewing. It consists of the display screen (1), the intensity-control knob (2), the beam-find button(3), the focus-control knob(4), and the power switch(5).



a. oscilloscope analog **b. Oscilloscope digital**

Figure 3. *Schematic of* Front panel of an oscilloscope with functional blocks labeled.

- **A display screen** is a visual output device that presents information in a visible form. It can be an image, text, or graphics. Where the face of the screen is divided up into a 2 dimensional grid (or axes or scale); say a 10x10 grid. A graph of voltage (on the vertical axis) vs time (on the horizontal axis) is displayed by the oscilloscope.

- **The intensity-control knob** is used to adjust the brightness of the trace.

- **The beam-find button** allows the user to locate the electron beam anytime it is off-screen.To keep the beam within the 8 by 10 centimeter screen, press the beam find button to briefly lessen the vertical and horizontal deflection voltages.

- **The focus-control knob** adjusts the electron beam for optimal trace resolution.

An analog oscilloscope is typically divided into four sections: the display, vertical controls, horizontal controls and trigger controls

III.3.2 Vertical controls

Vertical controls are used to position and scale the waveform vertically, as well as to regulate the input coupling and other signal conditioning parameters.

Vertical controls that are commonly used include:

- The vertical position control allows you to move the waveform up and down on the display.
- The 'CH1/BOTH/CH2' channel-selector switch, is a fundamental control on a dual-channel oscilloscope like the Tektronix. It allows users to choose which channels they want to display on the screen or whether they want to view both channels simultaneously.
- The volts-per-division (volts/div) setting varies the size of the waveform on the screen. The volts/div setting is a scale factor. If the volts/div setting is 5 volts, then each vertical division represents 5 volts and an entire screen of 8 divisions can display 40 volts from top to bottom

• Coupling: DC, AC, and GND : There are a few buttons, or sometimes a switch, are also used to select the coupling mode. The coupling relates to how the signal enters the scope. There are usually options for AC, DC, and GND, as well as a few more modes.

1. When the coupling is set to AC, a capacitor is placed between the scope input amplifier and the probe, allowing only AC signals to flow through.
2. DC mode is used to measure a signal's DC value or to examine both the AC signal and the DC level at the same time.
3. GND coupling disconnects the scope input and sets it to the ground, so a flat line trace will be displayed. This mode is used to set the scope to a known reference point for accurate DC measurements.

III.3.3 Horizontal controls

This is the time base. Use the sec/div control to set the amount of time per division represented horizontally across the screen.

The horizontal position control allows you to move the waveform left and right on the display.

■ The seconds-per-division (sec/div) setting varies the rate at which the waveform is drawn across the screen (also known as the time base setting or sweep speed). The sec/div setting is a scale factor. If the setting is 1 ms, then each horizontal division represents 1 ms and the entire screen of 10 divisions represents 10 ms

III.3.4 Trigger System and Controls

The trigger feature of an oscilloscope synchronizes the horizontal sweep at the correct point in the signal. This is required for accurate signal characterization. You can use trigger controls to stabilize repeating waveforms and capture single-shot waveforms.

By displaying the same piece of the input signal repeatedly, the trigger causes repetitive waveforms to appear static on the oscilloscope display. Consider the mess on the screen if each sweep began at a different point on the signal.

- ***TRIGGER COUPLING***

To select the trigger coupling, press this button. The real setting is displayed on the CRT (source, slope "COUPLING"). The trigger coupling in the sequence varies every time the COUPLING button is pressed, Eac AC—HFR—LFR

✓ AC : Attenuates trigger signal frequency components below 20Hz and blocks the DC component of the signal. AC coupling is useful for triggering on AC waveforms that have a large DC offset.

✓ HFR (High frequency reject): Attenuates high-frequency triggering signal components above 50kHz. HFR coupling is useful for providing a stable display of low-frequency.

✓ LFR (Low frequency reject) : Attenuates low-frequency triggering signal components below 30kHz and blocks the DC component of the trigger signal.

- ***TRIGGER LEVEL***

Rotate the control knob clockwise and the trigger point moves toward the positive peak of the trigger signal. Rotate it anti-clockwise to move the trigger point toward the negative peak of the trigger signal.When the setting (voltage) value is greater or less than the highest or lowest value of the waveform, the synchronization sweep stops.

Oscilloscopes are commonly used for measurement applications such as:

- Observing the wave shape of a signal
- Measuring the amplitude of a signal
- Measuring the frequency of a signal

- Measuring the time between two events
- Observing whether the signal is direct current (DC) or alternating current (AC).

IV. Etude experimental

IV.1 How to Make Readings on the Oscilloscope

a) Peak-to-Peak Voltage

Using the vertical-position knob, place a peak (positive or negative) on a horizontal line while maintaining the peak visible on the screen. Set the next (opposite sign) peak of the middle vertical line using the horizontal-position knob.

Count how many divisions there are between the positive and negative peaks. The tick marks further subdivide the divisions into 1/5 (0.2).

Multiply the number of divisions from step 3 by the channel's volts/div value.

b) *Period*

To align any edge of the signal with a vertical line, use the horizontal-position knobs. Place the next identical edge crossing on the X-axis using the vertical-position knob.

Count the number of divisions from one crossing to the next in the same direction along the horizontal line.

Step 3: Multiply the number of divisions by the sec/div setting.

Procedures:

1. Using the previously completed parameters, answer the following questions..
   - What is the setting on the Volts/Div control knob? _______ volts/div •
   - How many vertical divisions from peak-to-peak? _______ div •
   - What is the peak to peak voltage (Vpp)? Vpp = _______ volts/div *
   - What is the setting on the Sec/Div control knob? _______ ___ seconds/div •
   - How many horizontal divisions exist between positive going crossings? _______ div •
   - What is the period of the signal (T)? T = _______ seconds/div *
   - What is the frequency of the signal (f)? _______ ___ hertz •

2. The function generator will then be adjusted to output another signal, and the measurements from Step 1 will be repeated.

Generate a square wave between 6 and 12 kHz with an amplitude setting of 4 o'clock; and ensure that you show the signal from peak to peak and for at least one full cycle (period).

- How many vertical divisions from peak-to-peak? _______ div
- What is the peak to peak voltage (Vpp)? Vpp = _______ volts/div *
- What is the period of the signal (T)? T = _______ sec/div *
- What is the frequency of the signal (f)? _______ ___ hertz.
- Draw the displayed signal on Graph 2.

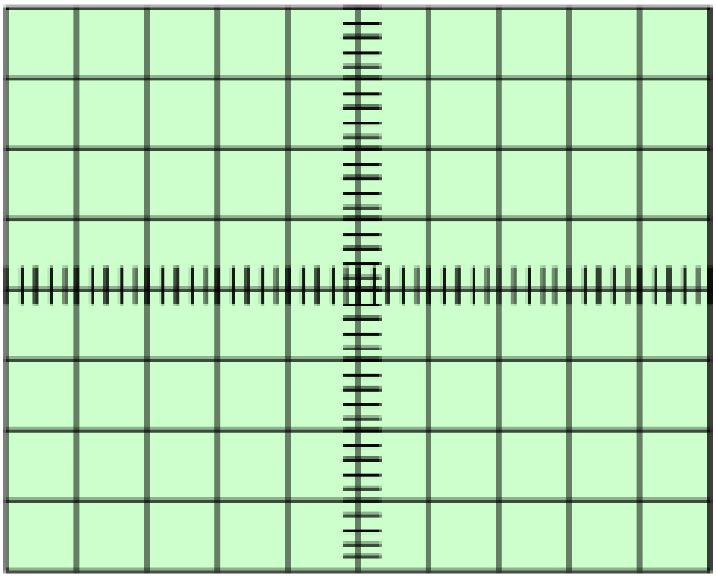


Figure 5.

3. Measurement of a direct voltage

We consider the following setup:

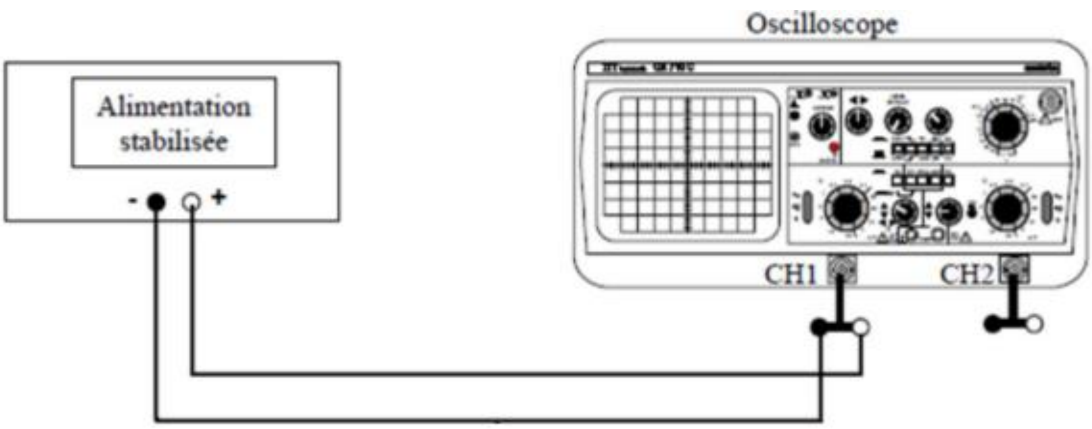


Figure 6 : Diagram of the DC voltage measurement setup

- Carry out the assembly in figure 5 above (the value of this voltage continues will be regulated by the teacher).
- Act on the vertical sensitivity button **"K"** (voltage gauge in Volts "V") to obtain a

horizontal line segment whose height, relative to the origin at the bottom of the oscilloscope screen, **"Y "** will be the largest possible and which corresponds to **Vmax,** i.e.:

➢ Measure the voltage **Vmax** and determine the absolute reading uncertainty committed on its measurement and express the result in a correct manner.

➢ Measure the same voltage with a digital voltmeter, determine the uncertainty in the measurement and express the result correctly.

4. Figure (6) shows a waveform displayed on the screen of an oscilloscope. Assuming the vertical sensitivity was set at 1.5 Volts per division. Use the information to answer questions 4.1, 4.2 and 4.3

- The peak value of the signal is:

(a) 6.75 Volts

(b) 7.50 Volts

(c) -6.75 Volts

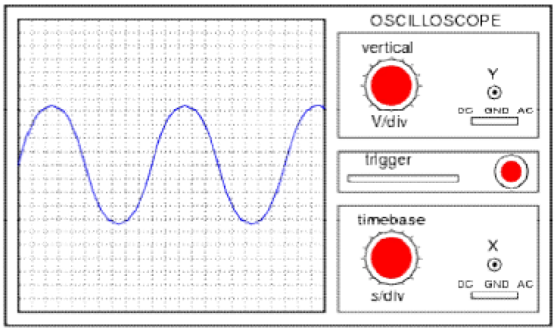


Figure 7:

- The peak-to-peak value of the signal is:

(a) 9.0 Volts

(b) 13.5 Volts

(C) 11.5 Volts

(d) -10.5 Volts

- Which control of an oscilloscope needs to be adjusted to get a better signal display than the one presented in Figure (e)?

(a) Vertical control

(b) Time base control

(c) Both vertical and time base controls

(d) None of the above

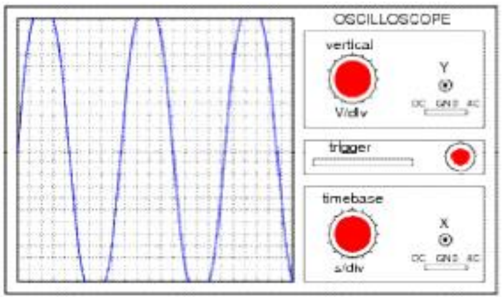


Figure 8 :

Which control of an oscilloscope needs to be adjusted to get a better signal display than the one presented in Figure (f)?

(a) Vertical control

(b) Time base control

(c) Both vertical and time base controls

(d) None of the above

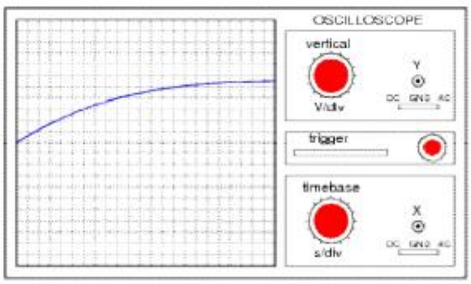


Figure 9:

V. Conclusions :

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Experiment 07

Wheatstone Bridge

Experiment N°7:

Wheatstone Bridge

I. SPECIFIC OBJECTIVES

- Understand the working principle of the Wheatstone bridge circuit,
- Determine the value of the unknown resistance using the Wheatstone bridge principle,
- Understand the Wheatstone bridge application.

II. Tools and Materials

You have the following equipment:

- ☑ (01) DC voltage generator $E = ... V$,
- ☑ (01) Rhéostat $R_{Rh} = ...\ \Omega$,
- ☑ (01) Ohmmèter,
- ☑ (01) Galvanomèter,
- ☑ two known resistances. R_1 et R_2 .
- ☑ Unknown resistor,
- ☑ Connector cable,
- ☑ breadboard,

III. BASIC THEORY:

III.1 Pont de Wheatstone

A Wheatstone bridge is a special type of electrical circuit that is used to accurately measure the unknown resistance of a component by balancing two legs of the circuit. The basic circuit of the Wheatstone bridge is shown in the figure below. He is used to provide accurate measurements. Wheatstone bridge consists of four arms (R_1, R_2, R_3, and R_4) of which two arms have known resistances and the other two arms consist of an unknown resistance and a variable resistance.

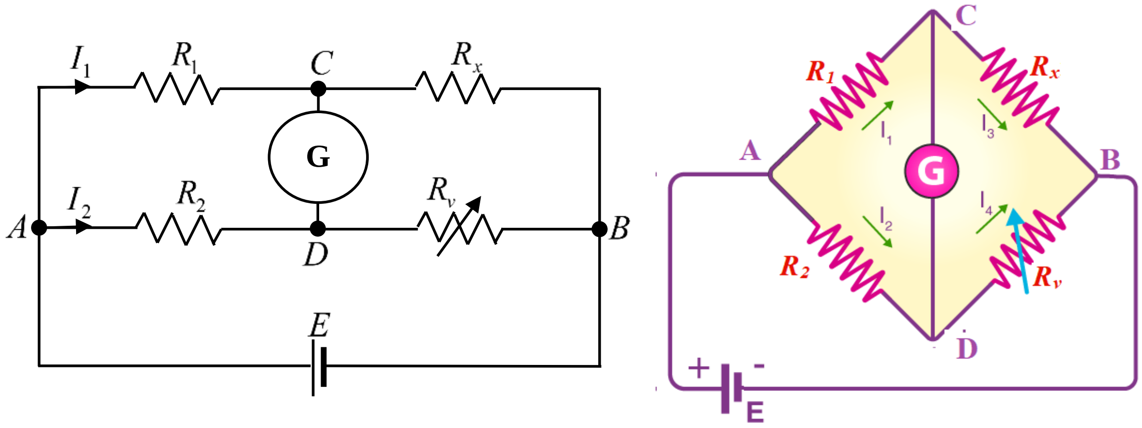

Figure 1: *schematic diagram of the Wheatstone bridge.*

In the figure, R_x is the fixed, yet unknown, resistance to be measured. R_1, R_2, and R_v are resistors of known resistance and the resistance of R_v is adjustable. The resistance R_v is adjusted until the bridge is "balanced" and no current flows through the galvanometer V_g. At this point, the potential difference between the two midpoints (**C** and **D**) will be zero. If the bridge is unbalanced, the direction of the current indicates whether R_v is too high or too low.

To determine the value of the unknown resistance R_x , it is necessary to adjust the variable resistance R_v in R_1 the bridge until one cancels the intensity of the current between the two branches of the bridge. So, by acting on the resistors R_1 , R_2 and R_v it is possible to cancel the current in the galvanometer.

The bridge is then said to be balanced. In this case we can write :

$$V_C - V_D = 0 \Rightarrow V_C = V_D .$$

This makes it possible to apply Ohm's law to the terminals of R_1 and R_2 :

$$V_A - V_C = R_1.I_1 \quad \text{et} \quad V_A - V_D = R_2.I_2 ,$$

from where : $$R_1.I_1 = R_2.I_2 \Rightarrow I_2 = \frac{R_1}{R_2}.I_1 .$$

On the other hand : $$V_C - V_B = R_x.I_1 \quad \text{et} \quad V_D - V_B = R_v.I_2 ,$$

So : $$R_x.I_1 = R_v.I_2 \Rightarrow I_2 = \frac{R_x}{R_v}.I_1 .$$

Therefore, the ratio of the two resistances in the known leg (R_2 / R_1) is equal to the ratio of the two resistances in the unknown leg (R_x / R_3).

$$\frac{R_x}{R_v} = \frac{R_1}{R_2} \Rightarrow \qquad \boxed{R_x = R_v \cdot \frac{R_1}{R_2}}$$

Note that it is useless to know the resistances R_1 and R_2 ; only their report intervenes ($K = \frac{R_1}{R_2}$) This report is called bridgehead report.

IV. Expérimental Procédures

- Arrange the circuit as shown in figure 1.
- Set the value of R_1 and R_2 then balance the bridge using R_v .
- Complete the following table

$R_1\,(\Omega)$						
$\Delta R_1\,(\Omega)$						
$R_2\,(\Omega)$						
$\Delta R_2\,(\Omega)$						
$R_v\,(\Omega)$						
$\Delta R_v\,(\Omega)$						
$K = \frac{R_1}{R_2}$						
$\frac{1}{K}$						
$\Delta\left(\frac{1}{K}\right)$						

- Detail the calculation of uncertainties here:

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- Draw the curve $R_v = f\left(\frac{1}{K}\right)$.

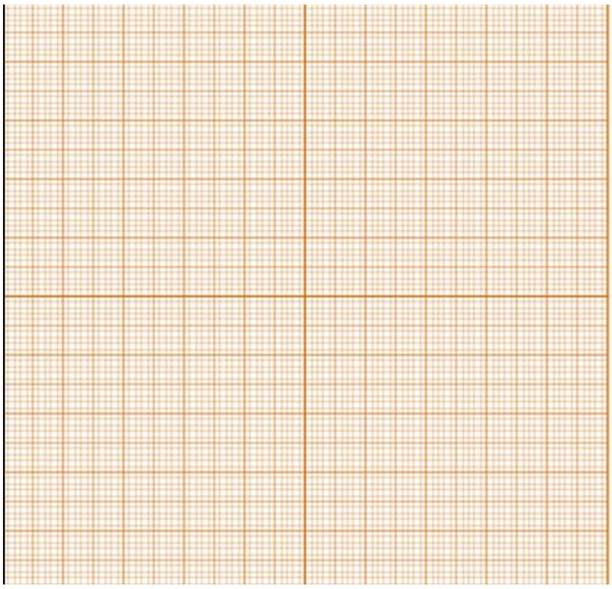

Figure 2 : *variation of the curve* $R_v = f\left(\frac{1}{K}\right)$.

- From this curve, deduce the values of R_x and ΔR_x ?

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IV. Conclusions :

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Experiment 08

Magnetism

Experiment N° 8:

Magnetism

I. SPECIFIC OBJECTIVES

The objectives of the magnetic field TP are as follows:

- ✓ *know how to use a teslameter to measure the intensity of a magnetic field,*
- ✓ *experimentally measure the evolution of the magnetic field inside a solenoid, a flat coil and 2 associated flat coils called Helmholtz coils,*
- ✓ *And finally to experimentally determine the magnetic permeability of the vacuum In this experiment, we will aim to learn about the following concepts:*

.

II. Tools and Materials

You have the following equipment:

1. (02) Coil (The width of each coil is 2L = 2.5cm, and their radius is R = 6.5cm.),
2. (01) a variable continuous power supply with intensity display,
3. (01) Teslamèter,
4. A magnetic needle
5. A compass,
6. Connector cable,

Figure .1: *Tools and Materials*

III. BASIC THEORY

A field, in physics, is a mathematical function defined over space (or space-time) that associates a physical quantity, or "field value," with each point in that space. These quantities can be scalars, vectors, tensors, or other geometric entities, depending on the nature of the field.

The description of a field involves specifying the quantity associated with each point in space, its mathematical properties, and its behavior under different conditions. Fields play a fundamental role in describing physical phenomena, from classical mechanics and electromagnetism to quantum field theory and general relativity. They provide a framework for understanding how physical quantities propagate and interact in space and time.

III.1. Detection of a Field

Fields, whether gravitational, electromagnetic, or others, are fundamental concepts in physics. Detecting their presence often involves measuring the effect they have on objects or instruments in their vicinity. Here are a few examples of how fields can be detected:

a. ***Gravitational Field Detection***: As mentioned, the presence of a gravitational field can be detected using instruments like a mass-spring system. When subjected to gravity, the mass in such a system experiences a force proportional to its mass and the strength of the gravitational field. This results in elongation or compression of the spring, which can be measured.

b. ***Electromagnetic Field Detection***: Electromagnetic fields can be detected using various devices depending on the frequency range and strength of the field. For instance: Magnetometers, Antennas and Hall Effect Sensors

c. ***Electric Field Detection***: Electric fields can be detected using devices such as: Electroscopes and Field Mill.

We are interested here in the magnetic field produced by magnets and electric currents. It is a vector field whose direction is given by a magnetic needle (south-north alignment) and whose intensity is obtained using a Hall effect probe.

In the international system of units, the magnetic field is expressed in Tesla (symbol: T)

III.2. Mode of representation

We can naturally represent the magnetic field by a set of vectors, in the same direction as the magnetic field, and whose Length is proportional to the intensity of the field .

For a magnetic dipole, the area where the vector arrows “exit” is called the North Pole, and the area where the arrows appear to enter is the South Pole. To represent the magnetic field, we can also use “field lines” (see figure 2).

These lines are defined by the following property: at each point M in space, the vector $\vec{B}(M)$ is tangent to the field line passing through M. We then have the following properties:

- A magnetic field line is always closed: it is oriented in the same direction as the field,
- The norm of the field is greater at a point (therefore, the field is more intense) as the field, lines are closer together.

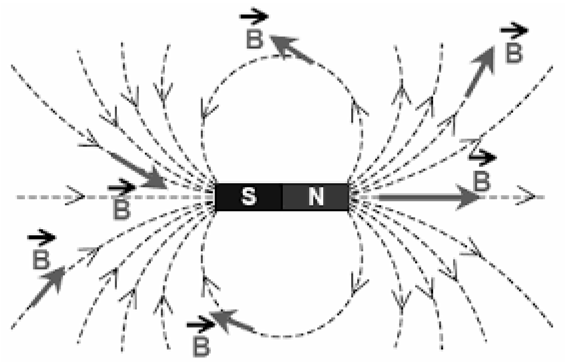


Figure .2. *Tools and Materials*

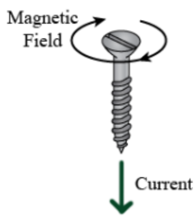
III.3 Determination of the Earth's magnetic field

III.3.1. Field created by a spiral

A turn of radius R traversed by a current I creates a magnetic field throughout space. If we place ourselves at the center of the turn, then the magnetic field has the following characteristics.

Intensity:

$$\boldsymbol{B} = \frac{\mu_0}{2R}\boldsymbol{I} \quad (1)$$



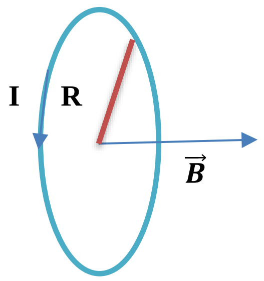
With $\mu_0 = 4\pi \times 10^{-7}$ SI :a constant called vacuum permeability.

Direction: following the axis of the turn.

The sense given by the corkscrew rule.

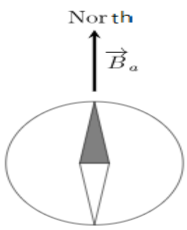
For N contiguous turns (glued to each other) forming a turn of negligible thickness, we can use the previous result provided that I is replaced by NI :

$$\boldsymbol{B} = \frac{\mu_0}{2R}\boldsymbol{NI} \quad (2)$$



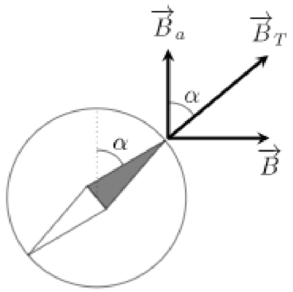
Measurement principle

The environmental magnetic field is the result of the Earth's magnetical field (approximately 10^{-5} T) and the inevitable electrical sources that also create not negligible magnetic Fields. The horizontal component of all these fields will be noted.



We will start by placing a compass in the center O of a spire when it is not passed by any current. The north pole of the compass then indicates the direction of $\overrightarrow{B_a}$. (diagram opposite). This position corresponds to a zero deviation of the compass (α = 0).

The spire is positioned so that its axis is perpendicular to $\overrightarrow{B_a}$.. When a current I circulates in the spire, it creates a magnetic field $\vec{B}$ which is added vectorially to the field $\overrightarrow{B_a}$. This results in a $\overrightarrow{B_T}$. field that makes an α angle with the compass's initial position. Fields $\overrightarrow{B_a}$. and $\vec{B}$. forming a straight angle, we can write: $\tan\alpha = \frac{B}{B_a}$



Place the second fine coil in its support so that the distance between the two coils is R. The two coils must be in series and the current I in the same direction in the 2 coils. This can be verified by measuring B which must be maximum in the middle and on the axis of the two coils.

IV. Experimental study

Unlike many quantities measured in physics, the magnetic field is not a scalar quantity but a vector, which makes its measurement more delicate. We will therefore use of two instruments to be able to know the magnetic field vector at a point M: first the compass, which will give the sense and direction of the magnetic field, then the probe of the teslameter which, placed in this direction, will give the norm of the vector

The aim of this practical work is to become familiar with magnetic field measuring instruments, as well as with some classic magnetic field creation devices.

IV.1 Field created by a simple coil

IV.1.1 Qualitative study

The coil is supplied with direct current. Using different measuring instruments available, answer the following preliminary questions:

1) Find the north pole of the coil. What happens when we change the meaning of current (draw a diagram)?

2) Find the points in space where the field is of maximum intensity, then the points of the space where the field is of minimum intensity. We will give the experimental method then a theoretical interpretation.

3) Show that the teslameter probe measures the projection of the field on its axis (we will detail the experiment carried out and its result).

4) What is the order of magnitude of the norm of the field created by the coil? Compare to Earth's magnetic field, conclude.

IV.1.2 Fields plots

1) Raise the direction (using a compass), then the norm (using the teslameter) of the magnetic field in about ten points from the horizontal plane passing through the center of the coil. Reports your results on a millimeter sheet of paper, choosing a suitable scale. We will not forget to note on the graph title and legend.

2) Move "hand" the teslameter probe around the coil to deduce approximately the appearance of the field lines.

The magnetic field produced by a filiform current distribution can be obtained by breaking the distribution into small current elements. We consider that each current element of oriented length $\vec{dl}$ crossed by a current of intensity I produces an elementary magnetic field in M

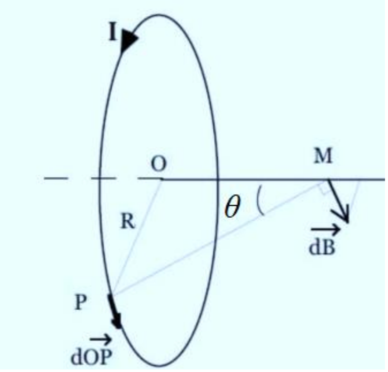
$$\overrightarrow{dB}(M) = k\frac{I\vec{dl}\wedge\vec{u}}{r^2} \qquad (4)$$

where I is the algebraic value of the current, $\vec{u}$ a unit vector oriented in the direction of the axis, and (θ_1, θ_2) the angles represented in the following figure:

By projecting the laws of Biot and Savart on z we will have :

$$\overrightarrow{dB_Z} = \frac{\mu_0}{4\pi\left\|\overrightarrow{PM}\right\|^2} I \sin\theta\, \overrightarrow{dP}$$

$$\overrightarrow{B_Z} = \frac{\mu_0}{2(R^2+Z^2)^{\frac{3}{2}}} NIR^2\vec{u} \qquad (5)$$



The purpose of this study is to verify relation (5) experimentally.

Connect the voice coil, have your assembly checked by the teacher before switching on tension.

1) In this part, we will set a value for the current.

- ✓ Measure the magnetic field at different points on the axis then plot its value algebraic B as a function of position z. What can you see?
- ✓ Then plot B $^{-2/3}$ as a function of z ^{2} (pay attention to the origin of the z).
- ✓ What interpretation can you draw from this curve? Do we find the result expected (qualitatively and quantitatively)?

IV.2. Coupling of two coils:

IV.2.1 Theory:

When several circuits have a current passing through them, the resulting magnetic field is the sum of the magnetic fields created by each circuit: this result, called the principle of superposition, is a direct consequence of Maxwell's equations.

In the present case where two identical coils are arranged coaxially and are crossed by the same current, the magnetic field on the axis can then be written in the following form

In the present case where the coils are flat and where their thickness can be neglected, these equations lead to the following expression for the field created by a coil on its axis:

$$\vec{B}(\theta_1,\theta_2) = \frac{\mu_0 NI}{2L}(\cos\theta_1 + \cos\theta_2)\vec{u} \qquad (6)$$

When several circuits have a current passing through them, the resulting magnetic field is the sum of the magnetic fields created by each circuit: this result, called the principle of superposition, is a direct consequence of Maxwell's equations.

In the present case where two identical coils are arranged coaxially and are crossed by the same current, the magnetic field on the axis can then be written in the following form:

$$\overrightarrow{B_Z} = \frac{\mu_0}{2R(R^2+(Z+d)^2)^{\frac{3}{2}}} NIR^2\vec{u} + \frac{\mu_0}{2(R^2+(Z-d)^2)^{\frac{3}{2}}} NIR^2\vec{u} \qquad (7)$$

IV.2.2 Experiment:

We will impose a fixed value on the current. Connect the two coils in series, have it checked your assembly by the teacher before turning on the power.

1- After having fixed the distance between the two coils (d>R, d<R or d=R), measure in different points on the axis the magnetic field created, then plot its algebraic value B depending on the position z.

2- What do you notice? Take a close look at the expected results (qualitatively and quantitatively)?

3- We can deal with questions 1 and 2 for the three cases: $d>R$, $d<R$ or $d=R$.

V. Conclusions :

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Report Experiment 1

Overview of the most common electrical measuring instruments

Report Experiment N°1: Voltmeter and Ammeter

Ammeter and voltmeter both devices are used in an electrical circuit to measure different aspects of electricity. Among them, an ammeter gives you the measure of current while the voltmeter helps in calculating the voltage or potential difference between two points in an electric circuit

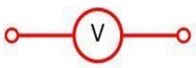
Connecting meters

It is important to connect meters the correct way round:

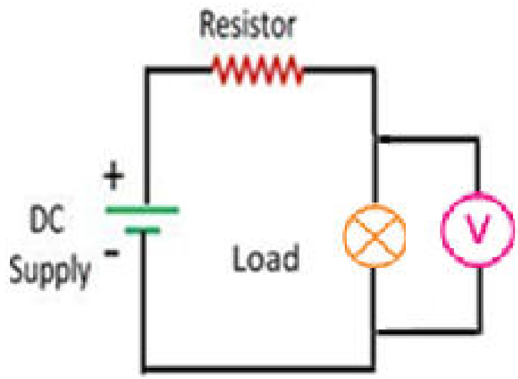
- The **positive terminal** of the meter, marked (+) or coloured red should be connected nearest to (+) on the battery or power supply.
- The **negative terminal** of the meter, marked (-) or coloured black should be connected nearest to (-) on the battery or power supply.

There are only two important things to read a multimeter correctly, which are focusing and

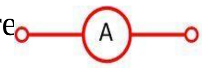
knowing the numbers/symbols. With a little effort and practice, anyone can do it well. We suggest you never try these things without enough education from your teachers. We hope this background study has helped you understand how to read an ammeter and voltmeter

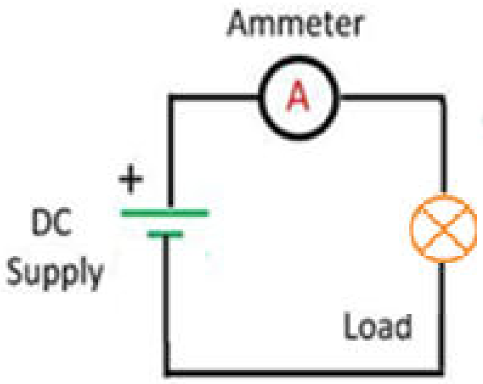
1°) A ***voltmeter*** of symbols 

, is a device that is used to measure voltage across two points in an electric circuit, it is connected in ***parallel*** with the circuit and its accuracy is less.



2°) A ***voltage*** source that is unchanging and constant over time is called a ***(DC) voltage***. While a voltage source that varies periodically in amplitude over time is called an ***(AC) voltage***.

3°) An ammeter is an essential device for measuring ***electric current*** flow of symbols . It measure  in ***amperes***, which is a unit of electric current. The intensity of the current, noted...***I***..... It is connected in ***series*** with the circuit and its accuracy is more; Some multimeters have a resolution of milli and micro amps denoted by mA and A respectively.



4°) What does caliber mean ?

Caliber is the greatest voltage (ampere) that a voltmeter (ammeter) can measure (the needle at the end of its movement for analog devices or the largest number on a digital display).

All modern devices are multicalibre: Caliber is changed by turning a switch or moving a plug.

4°) If we know the order of magnitude of the voltage or ampere to be measured, we choose the size just :

- above the estimated value
- below the estimated value

5°) If we have no idea of the value order of the voltage or ampere to be measured, we can keep :

- the highest of the device, then it is reduced.
- the smallest of the device, then we increase it.

6°) How to Read a Measurement from an Analog Instrument :

Find the right scale on an analog ammter or voltmeter. Analog ammeter or voltmeter have a needle behind a glass window, which moves to indicate the result.

Typically, there are two arcs printed behind the needle. These are two different scales, each of which is used for a different purpose:

After connecting meter to the power source check needle movement on screen, you have to count scale lines manually here. For example, if there are 10 lines in scale of 30 between 0 to 10v that means every line will indicate a change of 1. Similarly, if there are 10 lines in scale of 100 between 0 to 20, it indicates a change of 2.

For an ammeter, for example, the needle moves on two dials with respective maximum graduations of 30 and 100.

The indication read represents only a number of divisions. It is therefore necessary to deduce the intensity taking into account the caliber.

Calculate the values of i1, i2 and i3, from the readings taken on the two dials, taking into account the sizes chosen for each measurement.

Pour un ampèremètre, par exemple, l'aiguille se déplace sur deux cadrans de graduations maximales respectives de **30** et de **100**.

L'indication lue ne représente qu'un nombre de divisions. Il faut donc déduire l'intensité en tenant compte du calibre.

Calculer les valeurs de i1, i2 et i3, à partir des lectures faites sur les deux cadrans, en tenant compte des calibres choisis à chaque mesure.

$$value\ mesurad = \frac{caliber \times reading}{scale}$$

a°) **Caliber 0.3A**

Scale	**Reading**	**i_1 (A)**
30	6	$i_1=\frac{0.3\times6}{30}=\frac{1.8}{30}=0.06$
100	20	$i_1=\frac{0.3\times20}{100}=\frac{60}{100}=0.06$

b°) Caliber 1A :

Scale	**Reading**	**i_2 (A)**
30	15	$i_1=\frac{1\times15}{30}=\frac{15}{30}=0.5$
100	50	$i_1=\frac{1\times50}{100}=\frac{50}{100}=0.5$

c°) Caliber 3A :

Scale	**Reading**	**i_1 (A)**
30	24	$i_1=\frac{3\times24}{30}=\frac{24}{10}=2.4$
100	80	$i_1=\frac{3\times80}{100}=\frac{240}{100}=2.4$

Summary: From these six measurements, what can we conclude?

a°) We can conclude that when the caliber used is a multiple of 10, it is better to choose (100) as a reading dial.

b°) When the caliber used is a multiple of 3, it is better to choose (30) as reading dial

7°) Absolute uncertainty: $\Delta i_{total} = \Delta i_{reading} + \Delta i_{device}$, we consider that :

$$\Delta i_{lecture} = \frac{(1/2) graduation \times caliber}{scale}.$$

7.1) When reading from the dial of 100, $\Delta i_{reading}$ is then equal to :

☐ $\Delta i_{reading} = caliber/50$ ☒ $\Delta i_{reading} = caliber/100$

why ?.

...... because if we apply this formula $\Delta i_{reading} = \frac{(1/2) graduation \times caliber}{100}$.

we have graduction of this dial equal 2 so $\Delta i_{reading} = \frac{(1/2) \times 2 \times caliber}{100} = \frac{caliber}{100}$

7.3) When reading from the dial de 30, $\Delta i_{reading}$ is then equal to :

☐ $\Delta i_{reading} = caliber/30$ ☒ $\Delta i_{reading} = caliber/60$

why ?.

...... because if we apply this formula $\Delta i_{reading} = \frac{(1/2) graduation \times caliber}{30}$.

we have graduction of this dial equal 1 so $\Delta i_{reading} = \frac{(1/2)\times 1\times caliber}{30} = \frac{caliber}{60}$

7.1) Write the expression of Δi_{device} : $\Delta i_{device} = \frac{...class \times caliber..}{100}$.

8°) Conclusions :

The voltmeter measures the voltage difference between two points in the circuit while the ammeter measures the current flowing through the circuit. If we want to measure the current flowing through the load, we need to connect the ammeter in series with the load. While if we want to measure the voltage across the load, we need to connect a voltmeter in parallel with the load.

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