Introduction to Equipment and Essential Reminders

1. Purpose of the Experiment

The primary objective of this laboratory exercise is to familiarize students with electrical components, such as resistors, measuring instruments, and the wiring of direct current (DC) circuits. Specifically, we will explore the laws governing the relationship between charge and potential difference in resistors and their practical applications in measuring electric current.

2. Theoretical Overview

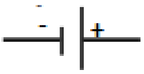
2.1. Measuring and Testing Instruments

A measuring instrument, or measuring device, is a tool used to experimentally determine values associated with specific physical quantities. A voltmeter measures the potential difference between two points in a circuit, while an ammeter is used to measure the current flowing through a circuit branch. An ohmmeter is employed to determine the resistance of a circuit segment. Additionally, potential differences can be analyzed with an oscilloscope, which will be discussed later. Each measuring instrument is equipped with two probes—wires that must be properly connected to the circuit to ensure accurate measurements. Details of the measuring equipment available in the measurement laboratory at the Faculty of Technology, University of M'sila, are provided in the attached appendix

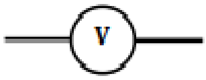
- Digital DC Power Supply with Analog and Digital Display
- Analog Voltmeter
- Analog Ammeter
- Digital Multimeter
- Oscilloscope
- Function Generator (Low-Frequency Generator, GBF)
- Test Bench
- Cables and Probes

.1.1. DC Power Supply

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

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

2.1.2. The Voltmeter

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

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

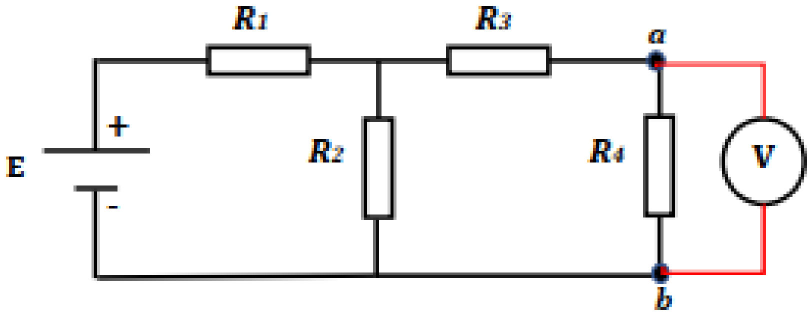


Figure 1: Voltage Measurement Using a Voltmeter

2.1.3. The Ammeter

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

The ammeter measures the current flowing through a branch of the circuit and must be connected in series with that branch to ensure the same current passes through both the branch and the ammeter. To take a measurement, the branch needs to be temporarily disconnected so the ammeter can be inserted into the circuit. In Figure 2, the ammeter is connected in series with resistor R4, allowing it to measure the current passing through R4.

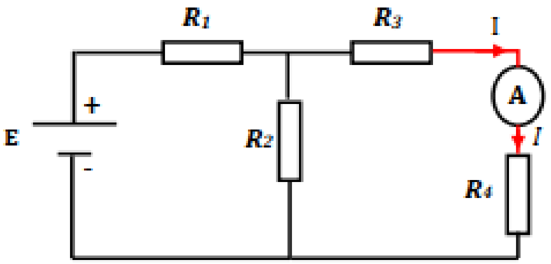
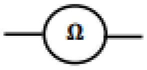


Figure 2: Current Measurement with Ammeter.

2.1.4. The Ohmmeter

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

Unlike voltmeters and ammeters, an ohmmeter is an active device with an internal battery that provides a known current to the circuit being measured. To determine the resistance of a single resistor or a combination of resistors, both probes of the ohmmeter must be connected to the resistor's terminals or the resistive network. It is essential to ensure the resistor is isolated from the rest of the circuit; otherwise, current from the circuit could mix with the ohmmeter's current, resulting in inaccurate measurements.

Figure 3(a) shows the correct method for measuring the resistance of R4 in the circuit from Figure 2. Notice that only one connection between R4 and the rest of the circuit has been disconnected. While both connections could be removed, it is unnecessary breaking the branch at any point is enough to stop current from flowing through R4.Figure 3(b) illustrates the correct method for measuring the combined resistance of resistors R3 and R4 connected in parallel

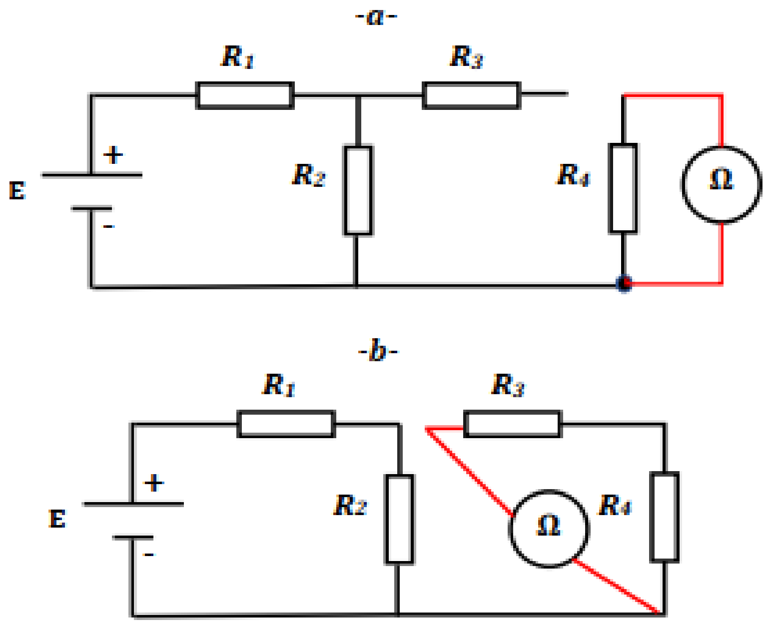


Figure 3: Resistance Measurement in an Electrical Circuit

2.1.5. The Multimeter

In practice, the instruments described above are often combined into a single device called a multimeter. A multimeter can be configured to function as a voltmeter, ammeter, or ohmmeter, with the option to select different sensitivity ranges. Analog instruments are typically based on a galvanometer, which operates using magnetic effects. However, analog devices have largely been replaced by digital displays, which are more affordable, durable, and precise. Unlike their analog counterparts, digital multimeters use electronic circuits with transistors to directly measure potential differences.

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

2.1.6. The Oscilloscope

While it can measure continuous potential differences, the oscilloscope is particularly well-suited for analyzing alternating voltages. It enables not only the measurement of amplitude but also the observation of waveforms over time. The oscilloscope consists of a cathode ray tube (CRT) enclosed in a vacuum-sealed glass envelope (see Figure 4). Electrons are emitted from a heated cathode and accelerated by a high voltage applied to an anode with a small aperture. The resulting electron beam strikes a fluorescent screen, producing a visible trace or spot.

Before reaching the screen, the beam passes between two pairs of deflection plates, each creating an electric field when a potential difference is applied. One pair of plates is oriented vertically, controlling horizontal deflection, while the other pair is horizontal, controlling vertical deflection. By adjusting the voltages applied to these plates, the electron beam moves across the screen, tracing a path that represents the signal being measured.

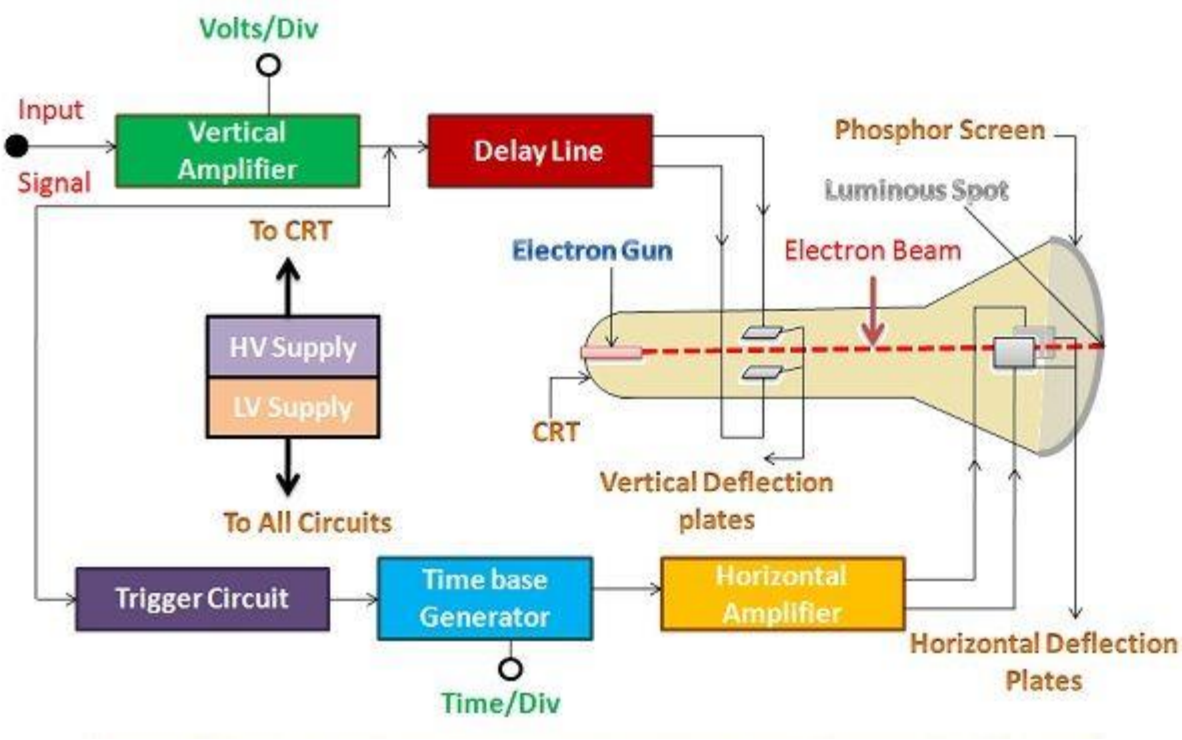


Figure 4: Schematic Diagram of an Oscilloscope.

The most common operating mode for the oscilloscope involves applying a sweep voltage to the vertical plates. This causes the spot to move from left to right across the screen at a constant speed, quickly returning to the left when it reaches the right edge. The potential difference being measured is applied between the horizontal plates, resulting in vertical deflection of the spot. This combination of horizontal and vertical deflections enables the observation of voltage variations over time on the screen.

2.1.7. The Function Generator

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

Figure 5: Low Frequency Generator (GBF).

2.1.8. The Breadboard

Before soldering a circuit, it is advisable to verify its functionality. A breadboard is an excellent tool for testing a circuit without the need for soldering, enabling quick checks to ensure there are no errors in the assembly. A breadboard consists of an insulating plastic board with numerous holes spaced 2.54 mm apart, which is the standard spacing for electronic components used in our assemblies. Using a breadboard is straightforward once one understands how the holes are interconnected (see Figure 6).

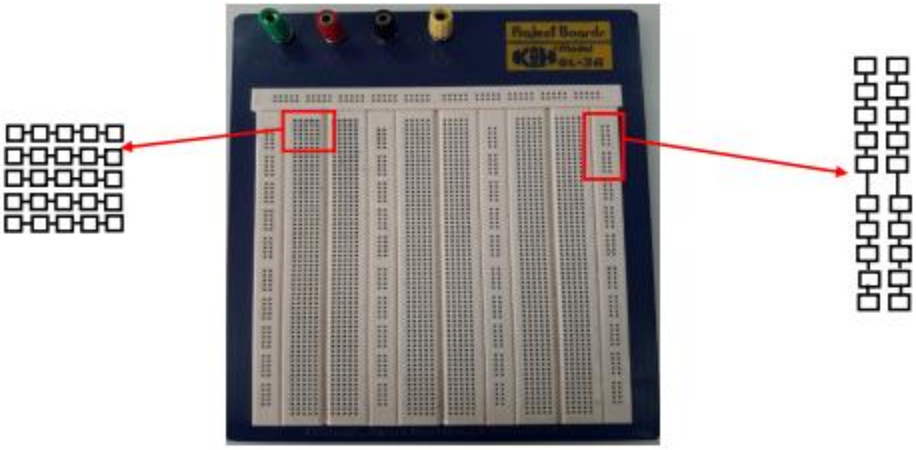


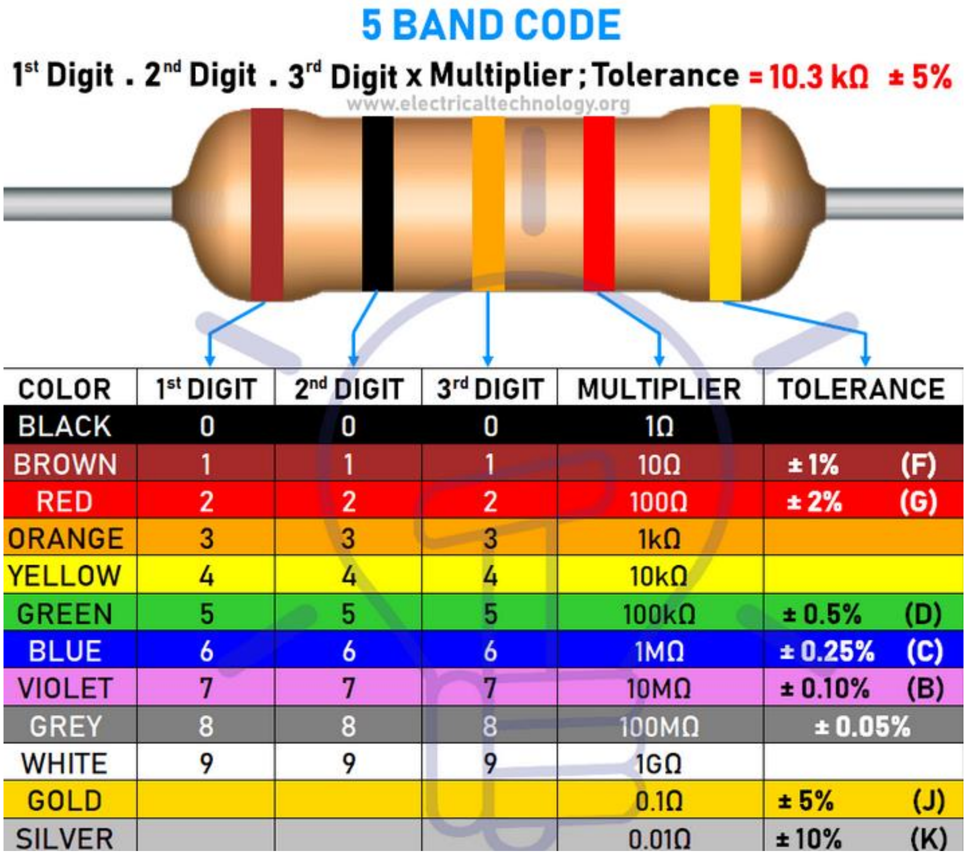
Figure 6: Breadboard

2.2. Introduction to Resistance

A resistor is an electronic or electrical component whose primary function is to oppose the flow of electric current, measured in ohms. Electrical resistance is a fundamental concept in the field of electricity. While the term "resistance" primarily refers to a physical property, it has also become synonymous with a specific type of component. Some people prefer to refer to it as a "resistive device."

2.2.1. Identification

To determine the ohmic value of a resistor, one must identify the color bands on the resistor (see Figure 7) and correlate them with the universal color code. The international standard IEC 60757, titled "Color Code Designation" (1983), specifies a color code used on resistors to indicate their resistance values.



COLOR	1st DIGIT	2nd DIGIT	3rd DIGIT	MULTIPLIER	TOLERANCE
BLACK	0	0	0	1Ω	
BROWN	1	1	1	10Ω	± 1% (F)
RED	2	2	2	100Ω	± 2% (G)
ORANGE	3	3	3	1kΩ	
YELLOW	4	4	4	10kΩ	
GREEN	5	5	5	100kΩ	± 0.5% (D)
BLUE	6	6	6	1MΩ	± 0.25% (C)
VIOLET	7	7	7	10MΩ	± 0.10% (B)
GREY	8	8	8	100MΩ	± 0.05%
WHITE	9	9	9	1GΩ	
GOLD				0.1Ω	± 5% (J)
SILVER				0.01Ω	± 10% (K)

Figure 7: Resistor Color Code

2.2.2. Series Connection of Resistors

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

Example: The equivalent resistance R of two resistors connected in series (see Figure 8) can be easily calculated. In this configuration, both resistors experience the same current intensity I .

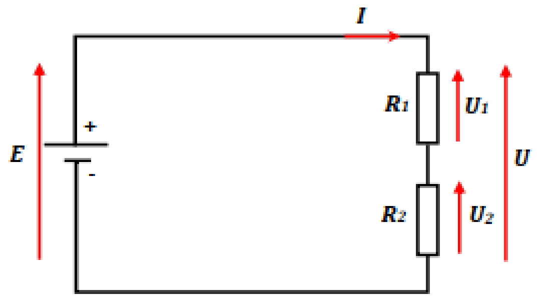


Figure 8: Resistors in Series

Using Ohm's Law, we can express:

$$U1=R1*I$$

$$U2=R2*I$$

The voltage U across the terminals of the two resistors R1 and R2 which are connected in series, is equal to the sum of the voltages across each resistor:

$$U=U1+U2 = R1*I+ R2*I= (R1+R2)*I, \text{ where } R1+R2=R$$

The resistance R represents the equivalent resistance of the two resistors R1 and R2 connected in series. Consequently, for N resistors arranged in series, the equivalent resistance can be expressed as:

$$\mathbf{R=R1+R2+R3+R4+\ldots\ldots.RN}$$

2.2.3. Parallel Connection of Resistors

In this configuration (see Figure 9), each of the two resistors, R1 and R2 , has one terminal connected to the positive (+) terminal of the power supply and the other terminal connected to the negative (-) terminal. As a result, both resistors experience the same voltage provided by the power supply. This condition is a defining characteristic of parallel connections, where the voltage across multiple components connected in parallel remains constant.

Example: Let us calculate the equivalent resistance R of the two resistors connected in parallel, as shown in Figure 9.

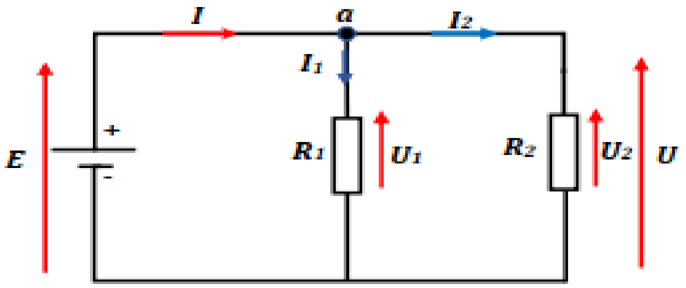


Figure 8: Resistors in Parallel

The two resistors R1 and R2 are subjected to the same voltage:

$$U=U_1+U_2$$

The sum of the currents entering a junction is equal to the sum of the currents leaving that junction, a principle known as Kirchhoff's Current Law. In junction a of Figure 8, we have:

$$I=I_1+I_2$$

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

$$U1=R1*I1 \text{ and } U2=R2*I2$$

$$I1= U1/ R1 \text{ and } I2= U2/R2$$

We have: $I=I_1+I_2= U/R_1+U/R_2= U(1/R_1+1/R_2)$

We can deduce the equivalent conductance, denoted as 1/R, as follows:

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

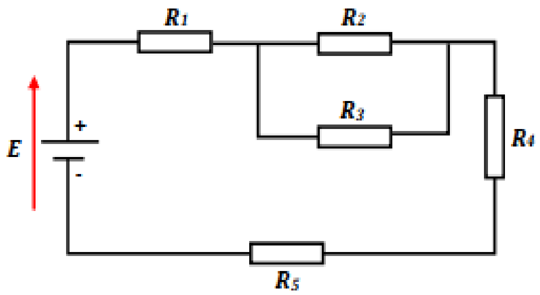
Consequently, for N resistors connected in parallel, the equivalent resistance can be expressed as:

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

3. Experimentation

3.1. Personal Work

1. Consider the following electrical circuit:

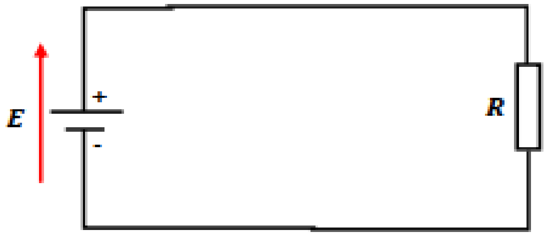


a. Redraw this circuit by including an ammeter to measure the current flowing through the resistor R3

b. Redraw the initial circuit to include a voltmeter for measuring the voltage drop across the resistors R4 and R5

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

2. Consider the following circuit:

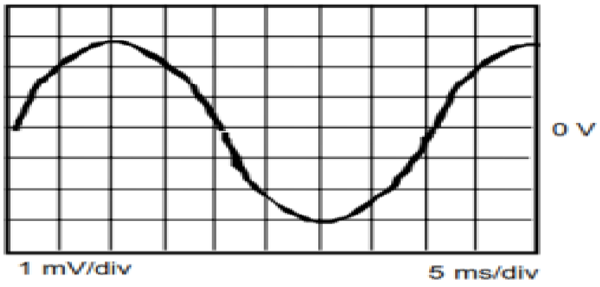


We aim to simultaneously measure the current flowing through resistor R using an ammeter and the voltage difference across Rwith a voltmeter.

Create a schematic diagram of the setup to be implemented.

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

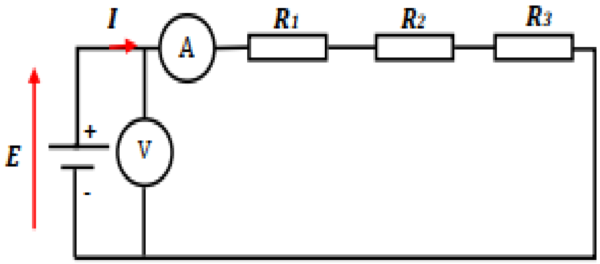
a. What are the amplitude, period, and frequency of this voltage?



3.1. In-Person Work

1. **Setup 1**

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



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

- The color code.
- An ohmmeter.

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

d. Using an ammeter, measure the current I.

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

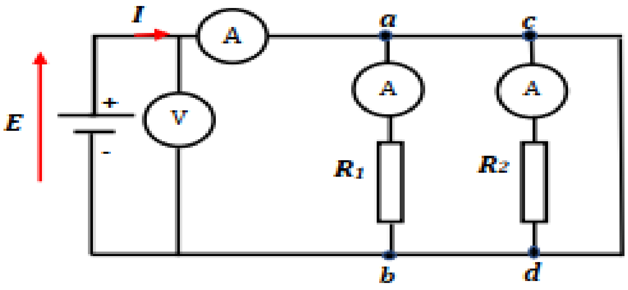
$$E=U1+U2+U3,$$

f. Deduce the values of resistances R1 R2 and R3 from the measurements obtained.

Compare these values with those found in part b.

2. **Setup 2**

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



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

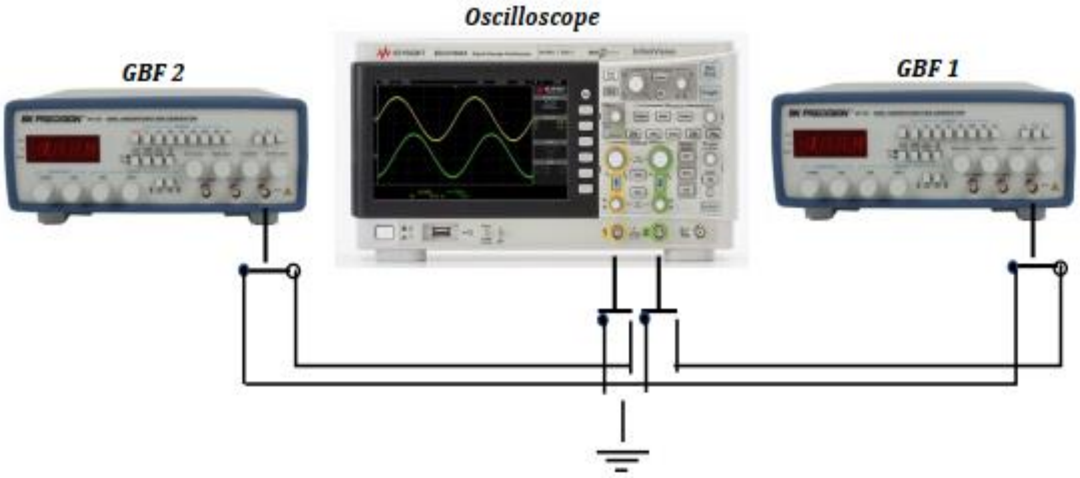
c. With the voltmeter, verify that the voltage across each branch (between points ab and cd) is equal to the supply voltage. Confirm the relationship:

$$E=U1(ab)=U2(cd)$$

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

3. Setup 3

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



b. Using GBF 1, generate a sinusoidal signal.

c. Using GBF 2, generate a triangular signal.

d. Visualize both signals on the oscilloscope.

e. Adjust the amplitude of the sinusoidal signal to 5V and the amplitude of the triangular signal to 10V, ensuring both signals have a period T of 0.001s.

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