Experiment N°1: Resistors measurement

I. Objective

1. Measure resistors by two different methods:

a)- “Upstream” or long derivation method.

b)- “Downstream” or short derivation method.

2. Compare, based on the error calculations, the effectiveness of each method then identify a judicious criterion for choosing between the two.

II. Theoretical reminders

Ohm's law teaches us in an elementary way that, to measure a resistance (R), we must know simultaneously: a)- The voltage at its terminals. b)- The current intensity (I) passing through it. To determine the resistance value (R), we take the voltage ratio (V) to the current (I):

$$R = \frac{V}{I} \tag{1.1}$$

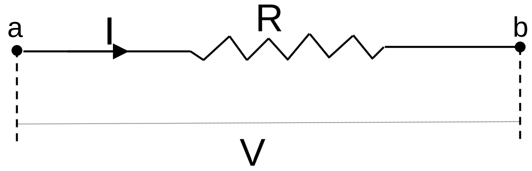

Figure 1.1: Ohm’s law

There are two possible arrangements for measuring both the current (I) using an internal resistance ammeter (r_a) and the voltage (V) using an internal resistance voltmeter (r_v):

II.1. Upstream method or long derivation:

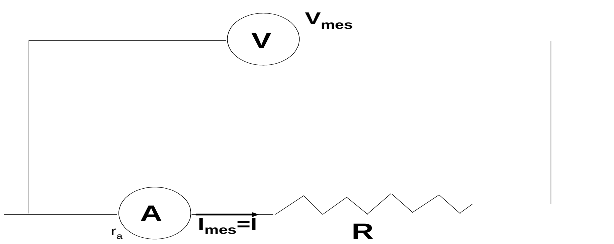

Figure 1.2: Upstream method (long derivation).

Let V_{mes} and I_{mes} be the values read on the voltmeter and the ammeter respectively. In this case we read the real current value: I_{mes}=I; but we read since we also measure the voltage drop across the ammeter. The voltmeter measures the voltage resulting from the series connection of the resistor (R) and the internal resistance of the ammeter (r_a):

$$V_{mes}=(R+r_a)\, I_{mes} \qquad \text{avec:} \quad R_{mes}=R+r_a \tag{1.2}$$

This method is known as long derivation or 'Upstream'.

Note that in this case, there is always a systematic error due to excess in the resistance measurement (R), which would be negligible if R>>ra .

Because an ammeter has a very small resistance, it must never be connected directly across a voltage source, because a large current will flow through it and burn it out.

II.2. Downstream method or short derivation

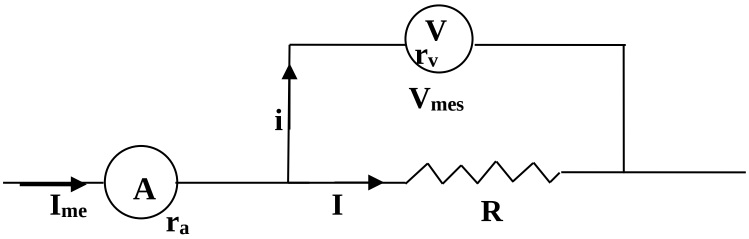

Figure 1.3: "Downstream" Method

Let V_{mes} and I_{mes} be the values read on the measuring instruments. The value read on the voltmeter is the true value of the voltage across the resistor (R): $V_{mes}=V$.

However, the ammeter does not indicate the current flowing through the resistor. The current (I) results from the voltmeter being connected in parallel with its internal resistor r_v and the resistor (R) to be measured. We then have:

$$\frac{1}{R_{mes}} = \frac{1}{R} + \frac{1}{r_v} \qquad (1.3)$$

This method is known as the short derivation or 'Downstream.'

It is important to note here that there is obviously a systematic error in the overall resistance measurement (R). This error becomes negligible if:

$\frac{1}{r_v} \to 0$ us a result $r_v \to \infty$ i.e. $\frac{1}{R} >> \frac{1}{r_v}$ therefore $R << r_v$

A Voltmeter has a high resistance as the result the small current which flows through it can usually be neglected without important error. For this raisin, it is protected from burnout, unless it is connected to a source of voltage substantially higher than its range.

II.2 Practice

Knowing that the absolute systematic error on the resistance measurement and using the previous equations, show that:

1. for long derivation, we have: $\left|\frac{\Delta R}{R}\right| = \frac{r_a}{R}$

2. For short derivation, and for low variations, i.e., for resistances $R<<r_v$, We have: $\left|\frac{\Delta R}{R}\right| = \frac{R}{r_v}$

III. Procedure
A/UPSTREAM branch or long derivation

- Using the voltmeter, the DC voltage delivered by the generator at **E=12 V** has been set.
- The circuit shown in Figure 4 has been produced. Note that the resistor **Rp=100Ω** introduced into the circuit is a protective resistor which serves only to prevent a short-circuit in the event of the variable resistor **R = 0 Ω**.
- The classes of the voltmeter and ammeter used have been recorded.
- Using resistors with real values of **R=1,2,3,...10 kΩ,** the voltages V_{mes} and corresponding currents I_{mes} have been measured for each resistor. Also note the gauge(s) used on the measuring equipment.
- Calculate the instrumental errors of the measuring devices (the voltmeter and the ammeter).

Note that in our case we are neglecting the errors due to the experimenter's reading, given its low values.

- Calculate the resistances measured using Ohm's law: $R_{mes}=V_{mes}/I_{mes}$
- Deduce the errors in the measured resistances (ΔR_{mes}) as a function of the instrumental errors (ΔV_{mes}) and (ΔI_{mes}).
- Complete the results presented in the following table:

R(kΩ)	**2**	**4**	**6**	**8**	**10**

V_{mes}( )	11,75	11,75	12	12	12,5
Range ( )	30	30	30	30	30
ΔV_{mes}( )					

I_{mes} ( )	4,3	2,6	1,7	1,25	1,05
Range ( )	10	10	3	3	3
ΔI_{mes}( )					

R_{mes}( )					
ΔR_{mes}( )					

- Plot the graph of $R_{mes}=f(R)$ with the error's bars.
- From the graph, deduce the value of the internal resistance of the ammeter (r_a).
- Calculate the systematic relative uncertainties values $|\Delta R/R|$ of the method in % which you should enter in the following table :

R(kΩ)					
$\|\Delta R/R\|$ in (%)					

- What can you see in these results?

B/Montage AVAL ou courte dérivation:

- Using the voltmeter, the DC voltage delivered by the generator at **E=12 V** has been set.
- The circuit shown in Figure 4 has been produced. Note that the resistor **Rp=100Ω** introduced into the circuit is a protective resistor which serves only to prevent a short-circuit in the event of the variable resistor **R = 0 Ω**.
- Using resistors with real values of **R=10, 20, 30,...100 kΩ,** the voltages V_{mes} and corresponding currents I_{mes} have been measured for each resistor. Also note the gauge(s) used on the measuring equipment.
- Calculate the instrumental errors of the measuring devices (the voltmeter and the ammeter).
- Calculate the resistances measured using Ohm's law: $R_{mes}=V_{mes}/I_{mes}$
- Deduce the errors in the measured resistances (ΔR_{mes}) as a function of the instrumental errors (ΔV_{mes}) and (ΔI_{mes}).

Complete the results presented in the following table:

R(kΩ)	20	40	60	80	100

V_{mes} ( )	12	12	11,75	11,75	12
Range ( )	30	30	30	30	30
ΔV_{mes}( )					

I_{mes}( )	0,62	0,34	0,25	0,17	0,14
Range ( )	1	1	0,3	0,3	0,3
ΔI_{mes}( )					

R_{mes}( )					
ΔR_{mes}( )					

$G=\frac{1}{R}$ (kΩ^{-1})					
$G_{mes}=\frac{1}{R_{mes}}$ ( )					
ΔG_{mes}()					

- Plot the graphic $\frac{1}{R_{mes}} = f\left(\frac{1}{R}\right)$ with <u>error's bars</u>.
- From the graph, deduce the value of the voltmeter's internal resistance (r_v).
- Calculate the relative systematic error values of the method $|\Delta R/R|$ in % and enter them in the table below
- From the graph, deduce the value of the voltmeter's internal resistance (r_v).
- Calculate the values of the relative systematic uncertainties $|\Delta R/R|$ of the method in % and enter them in the table below:

R(kΩ)					
$\mathbf{|\Delta R/R|}$ **in (%)**					

- What can you see in these results?

C/ Comparison between the two methods:

- Plot the two graphs on a new paper with the same scale $\left|\frac{\Delta R}{R}\right| = f(R)$ in both cases A (UPSTREAM assembly) and B (DOWNSTREAM assembly).
- Determine graphically the coordinates of the point M_0 (R_0, $|\mathbf{\Delta R/R}|$) where the two graphs intersect.
- Conclusions: Derive from the point M_0 a sensible criterion for choosing between the two methods.
- Use the equations to show that M_0 depends on the values of the internal resistance of the voltmeter and the ammeter. Calculate this value and compare it with the value of M_0 deduced from the graph. What do you find?

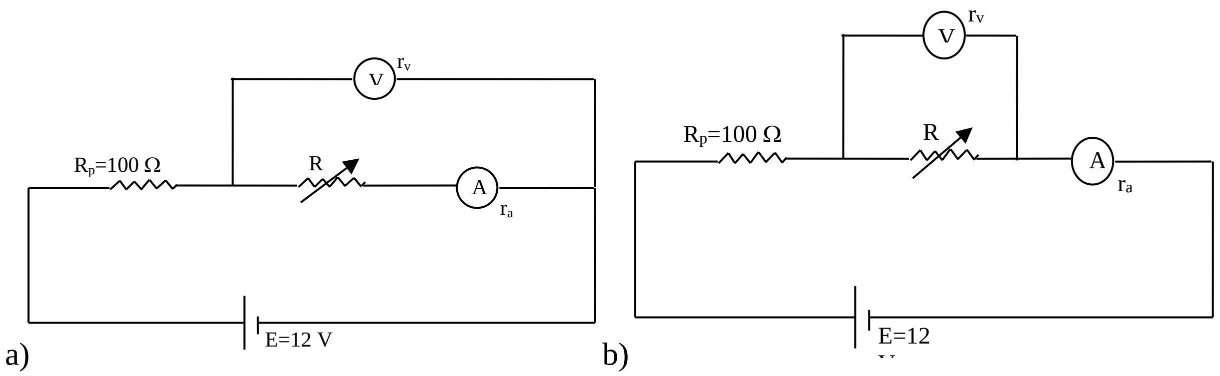

Figure 1.4: a) Upstream" or long derivation method; b) "Downstream" or short derivation method.

Notice : At the session end: Rehabilitation of the workstation.