Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

University of Applied Sciences Hamburg	DEPARTMENT OF ELECTRICAL ENGINEERING	**Laboratory for Instrumentation and Measurement**
Group No :	**HW Lab 1** Room 501	L1: in charge of the report
Date:		Assistant A2:
Professor:		Assistant A3:

Basic measurements of current, voltage and resistance

Report History

		Date		Remarks
Report 1	received			
	checked			
	result	o.k.		
		n.g.	➔ *1. Correction* ➔ Term..............................	
1. Correction		Date		Remarks
	received			
	checked			
	result	o.k.		
		n.g.	➔ 2. *Correction* ➔ Term..............................	Last chance!!
2. Correction		Date		Remarks
	received			
	checked			
	result	o.k.		
		n.g.	➔ ***not passed*** ➔ back to L1................	

Final decision:

☐ o.k.

☐ not passed   Prof. ....

Important

- no wiring before the presentation of a correct circuit diagram including all instruments
- maintain a logbook to document your experimental work.
- be familiar with instruments for measuring DC-voltage, current and resistance
- equivalent sources must be calculated in advance
- be familiar with Norton's and Thevenin' s Laws for equivalent sources

Objectives

- Understand and operate basic voltage and current measuring instruments and measure voltage-current and voltage-resistance characteristics step by step.
- Gain practical experience with different types of multimeters to measure current, voltage and resistance and the thorough preparation and evaluation of the measured data.
- Understand the relevance of measurement errors.

Preparation

Note:
This homework is to be prepared before the lab session starts and to be presented at the beginning of the lab session.

1. Preparation for task 1.3:
   Calculate each voltage drop in the voltage divider circuit and list these values in a table.
2. Preparation for task 2:
   Calculate the current between nodes A1 and A2, C1-C2, D1-D2, E1-E2 and F1-F2 and present this data in a table.
3. Preparation for task 3:
   Apply Norton's or Thevenin's law for equivalent sources and determine the equivalent resistance and the no-load voltage.
4. Read this information very carefully:

   Appendix 1: Introduction to measurement errors
   Appendix 2: Systematic errors and uncertainties
   Appendix 3: Influence of the internal resistance of multimeters (VM and AM)

Remember:

Use grid paper in the lab to make plots, circuitries and calculations.

Plot the wiring diagram including all required instruments and make a list of all important items in use.

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

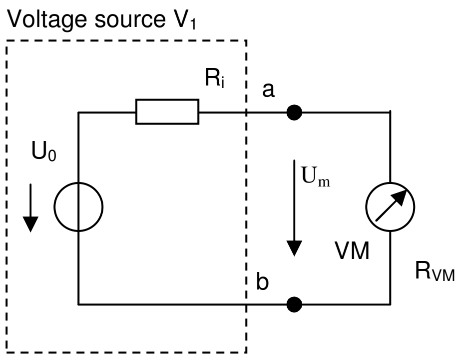
Experiment 1: Voltage Measurement

Experiment 1.1: Voltage drop and no-load voltage

Measure the voltage drop across the terminals a and b of a battery with different instruments. Enter all values into a prepared table.

Calculate the accuracy of each measurement and explain if the results of the different devices match.

Note: mind the correct number of significant digits



Experiment 1.2: Internal resistance R_i

Determine the internal resistance of the unknown source by applying the half-deflection method: Load the source with a power potentiometer R_p until the Metrawatt voltmeter 18S is indicating half of the original (no-load) value.

Now measure the resistance R_p with all multimeters and enter the values into a table (to be prepared prior to the experiment). Calculate the accuracy for each resistance measurement.

Attention:

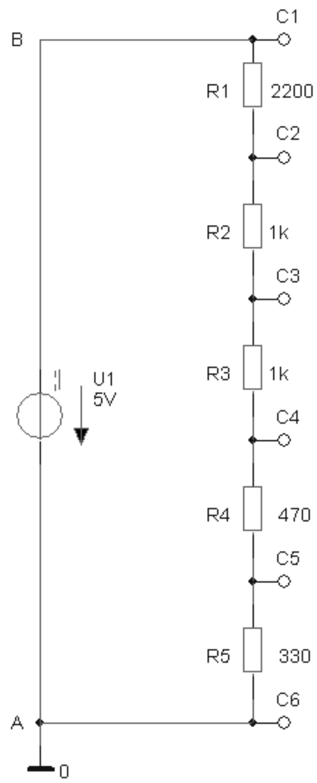
- Never connect an ohmmeter to a live circuit
- Never store an ohmmeter (or any multimeter) in the resistance mode

Experiment 1.3: Voltage divider

For each of the following experiments only use the digital voltmeter 18S or 26S.

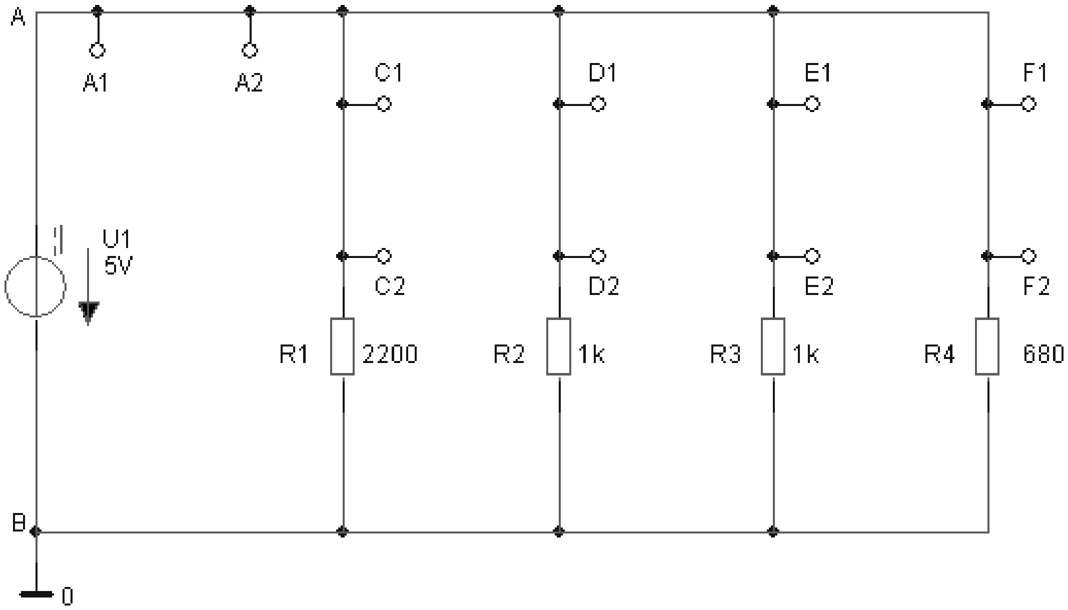
Connect the terminals A, B to a fixed voltage of +5.0 V.
Measure the voltage drop across the terminals as detailed below.

	C1-C2	C2-C3	C3-C4	C4-C5	C5-C6
calculated					
measured					
	C1-C3	C2-C4	C3-C5	C4-C6	
calculated					
measured					
	C1-C4	C2-C5	C3-C6		
calculated					
measured					
	C1-C5	C2-C6			
calculated					
measured					



Experiment 2: Current measurement

Connect a voltage source of U_B = 5.0 V to the terminals A and B and then insert an ammeter between A1- A2 and measure the current. Repeat the measurement for each pair of terminals C1-C2, …



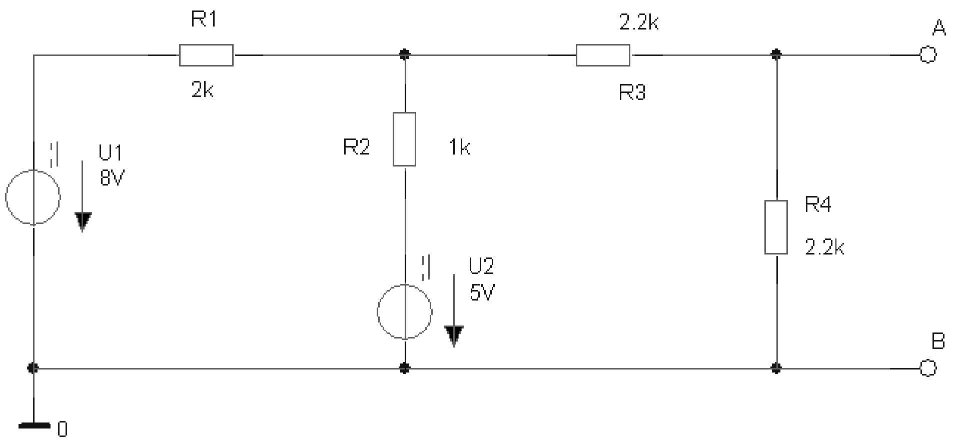
Compare the results with the predicted values and calculate the relative error for each measurement.

Remember:
In order to eliminate errors resulting from incorrectly connected elements in the given circuitry follow these rules:

- use cables of **different colours** to indicate the voltage at the connecting terminals: always red for (+), blue for ground (-) and, for instance, green for instrument connection (AM or VM)
- arrange all instruments and elements in a circuit according to the given circuitry plan
- connect the devices mesh by beginning with the source terminal A, and then ammeter A1, network, B (clockwise)

Exercise 3: no-load voltage and internal resistance

The variable voltage source is adjusted to 8V. This source is used to generate U_1. The 5V output of the voltage source is used to generate U_2. Set up the following circuit. Apply a series or parallel circuit of resistors to implement the values of the resistances as shown below.



Exercise 3.1: Open circuit voltage

Activate both sources. Measure the open circuit voltage $U_0 = U_{AB}$ and determine the internal resistance R_i by applying the half-deflection method.

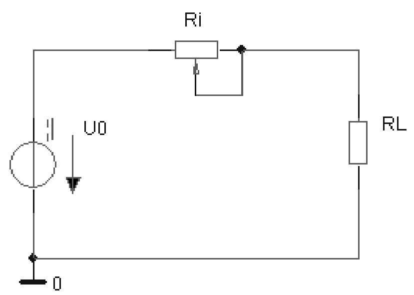
Exercise 3.2: Prove the equivalence of a linear voltage source

Connect a load resistor to the terminals A and B of the circuit illustrated above. Measure the load voltage and the current for each of the following resistances:

R_{L1} = 470 Ω
R_{L2} = 4,7 kΩ
R_{L3} = 10 kΩ

Draw a characteristic diagram U = f(I) of the voltage source based on these three data points.

Then attach the same 3 load resistors to a simple linear voltage source consisting of a voltage source adjusted to U_0 and a potentiometer set to $R = R_i$ that is to be connected in series with the voltage source. This circuit should be equivalent to the circuit with the two voltage sources as shown in the circuit diagram above. Add the points to the characteristic diagram.



Compare the measured values with the calculated results and determine the relative error for each measurement.

Appendix 1: Measurement errors

Definitions

Error: $E = x_m - x_t$

x_m: measured value
x_t: true value of the measurand

Relative error: $e = E / x_t = (x_m/x_t) - 1$

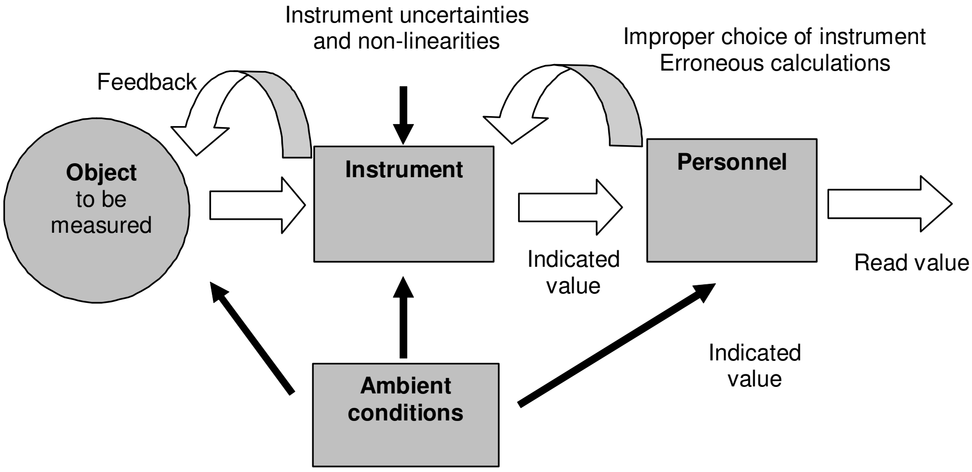
Correction: $C = - E$

As it is almost impossible to obtain the true value of a quantity that is to be measured, the most probable value or expected value (X_e) is often taken as the "true" value:

$$x_t \xrightarrow[N \to \infty]{} x_e = \frac{1}{N} \sum_{i=1}^{N} x_{m,i}$$

with N: number of measurements, $x_{m,i}$ result of measurement i

If a higher-precision instrument is available, this measured value can be taken as the "true" one. Errors occur in each experiment because they inevitably result from the measurement process. The block diagram shown below illustrates various ways in which the accuracy of a measurement can be compromised.



The accuracy of the value of the measurand can be affected by different sources, which can be roughly classified into the following classes:

a) systematic errors
b) uncertainties

Appendix 2: Systematic errors and uncertainties

Systematic error

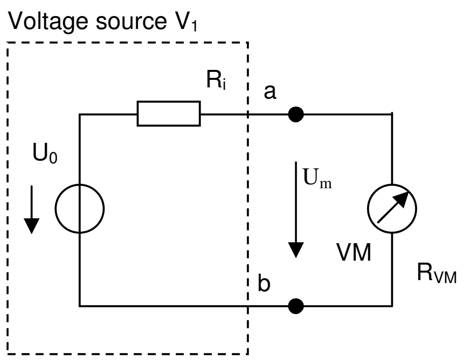
Putting an instrument into contact with the object that is to be measured will affect the measurement itself.

Examples:

- The heating or cooling process of a thermometer when it is placed into the medium whose temperature is to be measured.
- The loading effect on the input resistance (R_{VM}) of a voltmeter. If R_{VM} is known, the measurement error can be corrected:

Measurement U_m of the output voltage (no-load-voltage) of a linear (non–ideal) source:

$$U_m = \frac{R_{VM}}{R_{VM} + R_i} \cdot U_0$$



U_m: measured (indicated) value
U_0 : true value (ideal VM, $R_{VM} = \infty$)

Error: $$E = U_m - U_0 = -\frac{U_0}{1 + \frac{R_{VM}}{R_i}}$$

Relative Error: $$e = \frac{E}{U_0} = -\frac{1}{1 + \frac{R_{VM}}{R_i}}$$

The negative sign indicates that the measured value is always – systematically – less than the true one. If R_{VM} and R_i are known, the measured value can be corrected to determine the true value (U_{corr}).

The relative error e is small if $R_{VM} >> R_i$. Therefore it is important to know the internal resistance of any measurement device (here: Volt Meter) relative to the internal (equivalent) resistance R_i of the given source.

Note:
There is a simple test procedure to check the influence of R_{VM} on the resulting value of the measured voltage U_m: Add an additional test-device (VM) with the same resistance R_{VM} in parallel to the original voltmeter.

If there is a significant change in the indicated values you can be assured that R_{VM} is also affecting the value of the original circuit with only one VM, and that a correction C = -E is required:

$U_{corr} = U_M + C = U_M - E = U_0$

Uncertainties

The uncertainties (uncertainty limits L) present in measurement devices and standards used for comparisons can be determined in the following ways:

- manufacturers handbook of the instrument (→ specifications)
- indication of the grade marked on the instrument

The uncertainty of an instrument or standard may be specified in a number of different ways. Typical methods are:

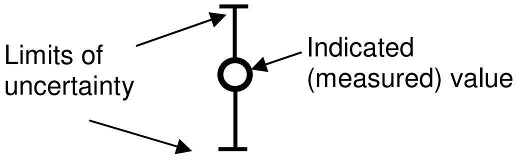
- standard instrument: uncertainty or percentage uncertainty of its value
- analogue instrument: percentage of its full scale reading (FSR)
- digital instrument: percentage of reading plus uncertainty due to digital resolution
  e.g. ± [0.1 % rdg + 2 D]
  rdg : of reading
  D: digit = least significant digit of the reading

Example:
A instrument is used on a 30V and displays 5 digits 30.000 V so that 1D = 0.001 V = 1 mV.
From the data sheet we obtain: [0.1 % rdg + 3 D]
The instrument indicates a measured voltage of 5.100 V.

The uncertainty limits L = ΔU of this instrument are:

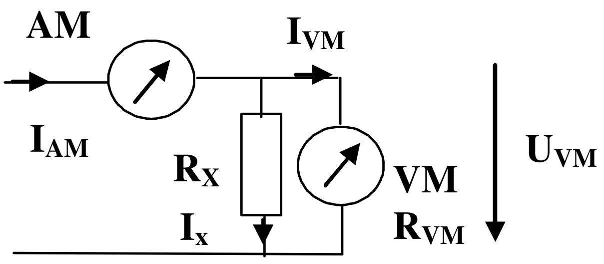
$$L = \pm\left[0.1 \cdot \frac{1}{100} \cdot 5.1V + 3 \cdot 1mV\right] = \pm 8.1mV$$

It is common to indicate a measurement and its limits of uncertainty graphically as follows:

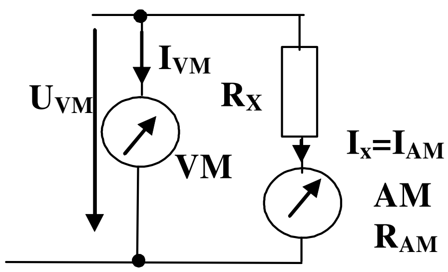


Appendix 3: Influence of the input resistance of VM and AM

There are two different ways to measure the unknown resistance of a resistor R_x, i.e., to measure its voltage drop U_X with a VM and the current I_X flowing through this resistor with an AM respectively:



True Voltage Method



True Current Method