HANDLING ERRORS WITH EXCEL SPREADSHEET

With the spreadsheet is possible **to calculate the errors** made on measurements, **write them properly** according the given rules, and also graphically draw the errors by means of the **error bars**. Let's see an example:

Example: Let's suppose that we are measuring the **voltage** (**V**) on terminals of a resistor (with a voltmeter) and the **intensity (I)** flowing along it (with an ammeter). According to **Ohm's law (R=V/I)**, the quotient between the voltage and the intensity will give us the value of such resistance. If we perform this measurement only one time, the error can be high, and to minimize it, we will do **several measurements** with different **couples of values V and I**, we will **graphically** draw the values measured (they must lye along a straight line), and **the slope** of such straight line **will give us the value of R** with lower error than if we had only done one measurement.

We suppose that the 4 couples of measured values are those on the table, and that the devices used to measure voltage and intensity have the following features:

V (V)	I (mA)
2,3	1,382
5	2,513
7,9	4,002
10,9	5,489

Voltmeter (V):

Type:	Analog
Full scale:	15 V
Class:	2
Reading error:	0,5 V

Ammeter (I):

Type:	Digital
Accuracy:	0,5 %
Reading error:	3 d

As an **example** of calculation of errors on voltage and intensity, we'll take the first couple of values (V=2,3 V and I=1,382 mA):

$\Delta V = \dfrac{2 \cdot 15}{100} + 0{,}5 = 0{,}8\, V$ In this case, **the error** on measurements of the **analog voltmeter** is the same for all the measurements, since it doesn't depend on the measurement (only on full scale, class and reading error). Besides, this error satisfies the rules of correct writing of errors (only one meaningful figure).

$\Delta I = \dfrac{1{,}382 \cdot 0{,}5}{100} + 3 \cdot 0{,}001 = 0{,}00991\, mA$ For **digital devices**, as the measurement influences the error, **the error is different for each measurement**. But now, the error calculated has too many figures, being necessary round it in accordance with the rules for writing errors $\Delta I = 0{,}010\, mA$ (two meaningful figures if they are lower than 25; 10<25). Then, the measurement of the intensity must be written with three decimal figures. The result of both measurements, properly written, is:

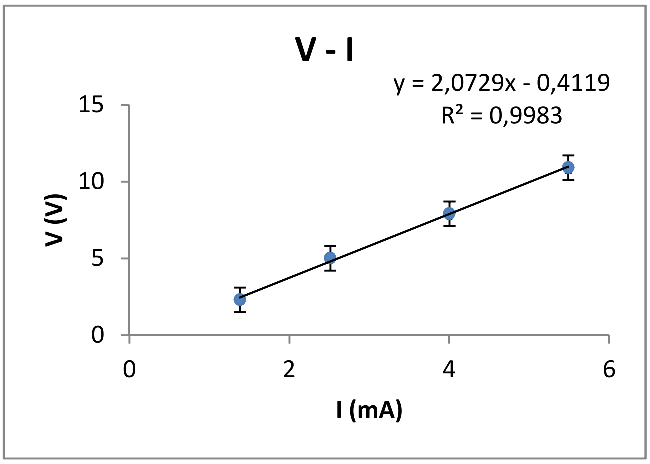
$$V = 2{,}3 \pm 0{,}8\, V \qquad\qquad I = 1{,}382 \pm 0{,}010\, mA$$

Computing in the same way the errors of voltage and intensity for the other measurements in the spreadsheet, and adjusting the number of decimals according the rules given by means of the option **"Format of cells/Number/Number-Formato de**

celdas/Número/Número” (clicking the right button of mouse after selecting the block of corresponding cells), the table of measurements remains in the following way:

V (V)	I (mA)	∆V (V)	∆I (mA)
2,3	1,382	0,8	0,010
5,0	2,513	0,8	0,016
7,9	4,00	0,8	0,02
10,9	5,49	0,8	0,03

When all the measurements are correctly written and their errors calculated, we will do **the graphic of V against I**, as we already know. But now, after the experimental points are drawn, we must also represent the errors calculated. To do it, clicking on graphic, in the tab **“Presentation-Presentación”** of **“Graphic Tools-Herramientas de gráficos”** appears the option **“Analysis-Análisis”**, and **“Errorr bars-Barras de error”**. Clicking in **“More options of error bars-Más opciones de las barras de error”** we can adjust both the horizontal error bars (in our case the intensity) as the vertical ones (in our case the voltage). If we choose the option **“Customized-Personalizada”** we’ll be able to choose if we want rounding by excess or by defect; to do it, we have to specify the range of cells. If the errors calculated are very small, it is possible that in the graphic we cannot distinguish the error bars. If we draw the previous data with their error bars, and we perform a linear fitting, we will have:



From this **linear fitting** we obtain that the **slope of this straight line** (value of the resistance) **is R=2,0729 KΩ**. From this linear fitting, we cannot obtain the **absolute error of the resistance** calculated, but we can do it if we use the function of Excel **“Estimación.Lineal”**.

Error of linear fitting. Function Estimacion.Lineal

On the spreadsheet we must select a block of 6 empty cells (3 rows x 2 columns); with these cells selected, in the bar of formulas we enter the symbol **“=”** and in the pull-down menu on left, we choose the function **“ESTIMACION.LINEAR”**. A window will be opened, with four values to be entered: the range of **“cells with the values to be adjusted on Y axis-celdas con los valores a ajustar del eje Y”**, the rank of **“cells with the values to be adjusted on X axis-**

celdas con los valores a ajustar del eje X", and in the two remaining options, **"1"** and **"1"**. Then, **without pressing Accept-Aceptar**, keys **"Ctrl+Shift+Enter"** must be **simultaneously pressed**, appearing six values on the selected cells that in our case would be:

2,07289683	-0,41194924
0,06007301	0,22147765
0,99832311	0,18587688

The values of the first row correspond to the slope and ordinate on the origin of the straight line resulting of linear fitting that has already been obtained. The values of the second row correspond to the absolute errors of slope and ordinate on origin; so, if we round the errors and we write properly the measurements, the slope (m) and ordinate on origin (y_0) of the resulting straight line would be:

$$m = R = 2{,}07 \pm 0{,}06\ K\Omega \qquad\qquad y_0 = -0{,}41 \pm 0{,}22\ V$$

The first value of the third row is the coefficient of correlation (R^2), saying us if the adjusting among experimental points and linear fitting is good or not. The last value isn't interesting for us.

It results **interesting to compare** this result obtained for resistance with the error computed from anyone of the measurements according the theory of error propagation, as it will be explained on next practice. As an example, if we consider the **second measurement (V=5 V and I=2,513 mA)**, the quotient V/I gives as result **R=1,99 KΩ** (similar to the calculated with the linear fitting), but the error calculated according the theory of error propagation (next practice) on this measurement is **ΔR=0,3 KΩ**, **5 times that obtained by means of linear fitting (ΔR=0,06 KΩ)**.