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Faculty of sciences - common Basic of matter sciences

1ST PRACTICAL WORK: ESTIMATION OF THE INACCURACY IN PHYSICAL MEASUREMENTS (EVALUATION OF ERRORS)

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	First Name	Family name	Subgroup	Professor's name
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Purpose

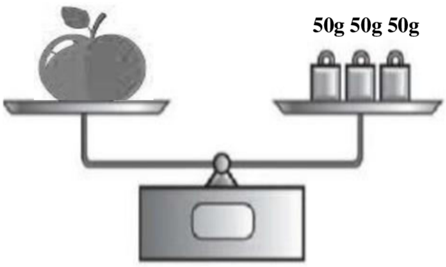
During experiments, we often need to provide values for specific quantities. Since obtaining the exact true value is usually impossible, it becomes crucial to understand and account for the uncertainty that arises during the measurement process. This uncertainty is typically expressed as a value that describes the deviation from the true value of the measured quantity.In practical terms, we aim to provide the most accurate or closest approximation to the true value, rather than the absolute truth itself. Therefore, it is essential to include the uncertainty value alongside the measured quantity. Estimating uncertainty in experimental work holds great significance because it allows us to assess how closely our measured value aligns with the true value, verify the accuracy of our measurements, and bolster the credibility of our results.The primary objective of this applied work is to develop the skills needed to estimate the uncertainty associated with measured quantities, including those derived from mathematical expressions.

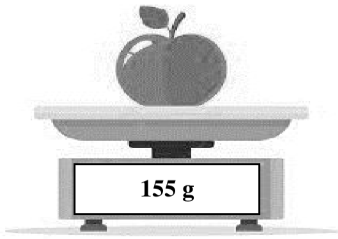
THEORETICAL REMINDER OF BASIC CONCEPTS

1. The meaning of the uncertainty in physical measurements

The concept of uncertainty can be understood through the following example:

The concept of uncertainty is exemplified when weighing the same apple using both a digital scale and a Roberval scale, which yields nearly identical measurements due to the minimal difference between the two.





This slight difference that we record in measuring a certain amount is expressed as uncertainty.

Important note: When measuring and estimating uncertainty values, it is essential to consider the scientific logic aspect. The uncertainty value should not exceed the value of the quantity, and the value of the quantity should not be exaggerated (the weight of an apple is equal to 2 kg).

2. Causes of measurement uncertainty

Among the most important reasons leading to uncertainty are:

- ✓ Using inaccurate or inappropriate measuring tools. For example, see **Figure -1-** and read the length of the black piece using the three rulers.

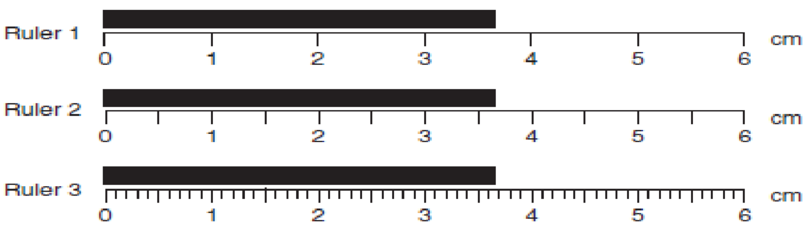


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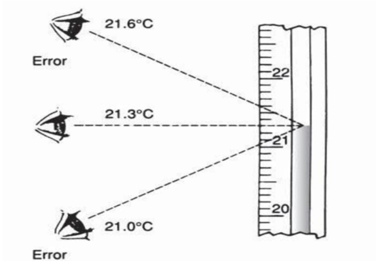
Figure -1-

- ✓ Using old measuring tools
- ✓ Measurement in incorrect positions, such as far away from the measuring instrument or measuring in a sideways or inclined position. For example, see **Figure -2-** that shows the difference in results depending on the reading position.



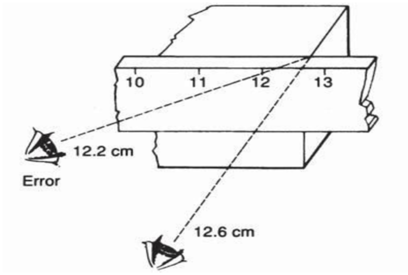


Figure -2-

- ✓ The effect of some factors such as temperature (expansion of measuring instruments).
- ✓ Rounding the measured values.
- ✓ Poor eyesight of the experimenter.

3. *Estimating the uncertainty of physical measurements*

The uncertainty in the measured quantities is estimated directly (reading the value directly from the instrument) or indirectly (using mathematical relationships linking a group of measured quantities) based on some statistical parameters such as:

3.1 For Direct Measurement

- **The Mean Value ($\bar{x}$):** It is obtained by dividing the total sum of measurements (x_i) by the total number of measurements (n). Its expression is given as follows: $\bar{x} = \frac{\sum_i x_i}{n}$
- **The Absolute Uncertainty (Δx):** This represents the absolute magnitude of the largest difference between the measured values and the mean value. Its expression is given as follows:

$$\Delta x = max|x_i - \bar{x}|$$

- **The Relative Uncertainty ($\frac{\Delta x}{\bar{x}}$):** It signifies the proportion of the absolute Uncertainty in relation to the mean value. Its expression is given as follows: $\Delta x/\bar{x} = \frac{\Delta x}{\bar{x}}$
- **The Mean Absolute Uncertainty ($\Delta\bar{x}$):** This refers to the average of the variances between the measured values and the mean value. Its expression is given as follows: $\Delta\bar{x} = \frac{\sum_i |x_i - \bar{x}|}{n}$
- **The Mean Squared Uncertainty (σ):** It denotes the average of the squared variances between the measured values and the mean value. Its expression is given as follows: $\boldsymbol{\sigma} = \sqrt{\frac{\sum_i (x_i - \bar{x})^2}{n-1}}$

3.2 For Indirect Measurement

In such situations, we determine a quantity's value through mathematical relationships with other variables. Indirect measurement is chosen when it's not feasible to directly measure the quantity or when a more detailed analysis is needed to explore how specific variables affect it. We can evaluate the absolute or relative uncertainty of a physical quantity G, which is expressed as a function of other variables, using the differential method for uncertainty estimation as follows:

$$if\ G = f(x, y, z, \dots.) \rightarrow \quad \Delta G = \left|\frac{\partial f}{\partial x}\right| \Delta x + \left|\frac{\partial f}{\partial y}\right| \Delta y + \left|\frac{\partial f}{\partial z}\right| \Delta z + \cdots \dots$$

THEORETICAL PART

The measurements of the period of a simple pendulum (as shown in the figure) are given in the following table:

	1	2	3	4	5	6	7
T(s)	0.75	0.68	0.72	0.74	0.71	0.73	0.69
$\|T_i - \bar{T}\|$							

1- Write and calculate the expression that represents the mean value for the period $\bar{T}$

……
……........

2- Calculate $|T_i - \bar{T}|$ for all measured values, then deduce the absolute uncertainty ΔT and the Relative Uncertainty

……
……....................

3- Calculate the mean absolute uncertainty $\Delta\bar{T}$

……..

4- Calculate the Mean Squared Uncertainty (σ)

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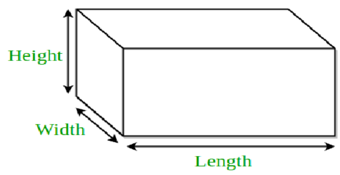
……...................

5- Write the quantity « T » in the form $T = \bar{T} \pm \Delta T$……………………………………………..

PRACTICAL PART



Choose an object with a Rectangular Parallelepiped shape, and measure its length, width, and height multiple times. Write the results in the following tables.

Lenght	1	2	3	4	5	6
L(s)						
$\|L_i - \bar{L}\|$						

1- Write and calculate the expression that represents the mean value for the period $\bar{L}$= **………..**

2- Calculate $|L_i - \bar{L}|$ for all measured values, then deduce the absolute uncertainty ΔL and the Relative Uncertainty $\Delta L =$ ……………… $\frac{\Delta L}{\bar{L}}$ =………………

3- Calculate the mean absolute uncertainty $\Delta\bar{L}=$ ………………………………………

4- Calculate the Mean Squared Uncertainty (σ)= ……………………………………

5- Write the quantity « L » in the form $L = \bar{L} \pm \Delta L$

………………………………………………………………

Height	1	2	3	4	5	6
H(s)						
$\lvert H_i - \bar{H} \rvert$						

1- Write and calculate the expression that represents the mean value for the period $\bar{H}=$ ……….

2- Calculate $\lvert H_i - \bar{H} \rvert$ for all measured values, then deduce the absolute uncertainty ΔH and the Relative Uncertainty $\Delta H =$ …………….. $\frac{\Delta H}{H} =$……………..

3- Calculate the mean absolute uncertainty $\Delta\bar{H}=$ ………………………………………

4- Calculate the Mean Squared Uncertainty (σ)= ……………………………………

5- Write the quantity « H » in the form $H = \bar{H} \pm \Delta H$ ………………………………………

Width	1	2	3	4	5	6
W(s)						
$\lvert W_i - \bar{W} \rvert$						

1- Write and calculate the expression that represents the mean value for the period $\bar{W}=$ ……….

2- Calculate $\lvert W_i - \bar{W} \rvert$ for all measured values, then deduce the absolute uncertainty ΔW and the Relative Uncertainty $\Delta W =$ …………….. $\frac{\Delta W}{W} =$……………..

3- Calculate the mean absolute uncertainty $\Delta\bar{W}=$ ………………………………………

4- Calculate the Mean Squared Uncertainty (σ)= ……………………………………

5- Write the quantity « W » in the form $W = \bar{W} \pm \Delta W$ ………………………………………

Compute the volume of the Rectangular Parallelepiped (V) for each measurement and then formulate expressions for both the absolute ΔV and relative uncertainties ($\Delta V/\bar{V}$ of the volume based on the absolute and relative uncertainties of the other quantities

	1	2	3	4	5	6
V(s)						

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………

………

………