Particle Work Of Physics 1

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1 st year licence common Basic

PW01 :

ESTIMATION OF THE INACCURACY IN PHYSICAL MEASUREMENTS

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Objectifs

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 :

- Use usual measuring instruments: caliper and balance
- Calculate uncertainties.

Introduction

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 asses show closely our measured value aligns with the true value, verify the accuracy of our measurements, and bolster the credibility of our results.

Physics and Measurements

I THEORETICAL REMINDER OF BASIC CONCEPTS

1. The meaning of the uncertainty in physical measurements

Almost every time you make a measurement, the result will not be an exact number, but it will be a range of possible values. The range of values associated with a measurement is described by the uncertainty. The uncertainty is a number which follows the ± sign. For example, in the measurement (8 ± 2), 8 is the value, and 2 is the uncertainty. Since all of science depends on measurements, it is important to understand uncertainties and get used to using them. The uncertainty in a measurement is sometimes called the “error”. This is an outdated term, because the word “error” implies that some kind of a mistake has been made. On the contrary, uncertainty is a necessary part of any measurement, and it would be a mistake not to report it (*ing-st.univ-batna2.dz*)

2. Estimating the uncertainty of physical measurements

Two different measurement methods have to be distinguished, direct and indirect measurement

2.1. Direct and Indirect Measurement

Définition

An error may be defined as the difference between the measured and actual values.

$$\delta = x_r - x_m$$

Where x_r is the real value (experimentally the average value), and x_m : is the real value measured

2.1.1. For direct Measurement

The Mean Value 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:

$$\bar{x} = \sum_{i=1}^{n} x_i / n$$

The Mean Absolute Uncertainty (Δx̄): This refers to the average of the variances between the measured values and the mean value. Its expression is given as follows:

$$\Delta \bar{x}=\frac{\sum_{i=1}^{n}|x_i-\bar{x}|}{n}$$

T***he 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

$$\sigma=\sqrt{\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n-1}}$$

The Absolute Uncertainty (Δx): This represents the absolute magnitude of the largest difference between the measured values and the mean value. It s expression is given as follows:

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

Or the maximum value that an error can take

$$\Delta x=max\,|\delta e|$$

2.2. 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 more detailed analysis is needed to explore how specific variables affect it. We can evaluate the absolute or relative uncertainty of a physical quantity x=f (a ,b ,c,..) , which is expressed as a function of other variables, using the differential method for uncertainty estimation as follows:

$$\Delta x=|\frac{\delta f}{\delta a}|\Delta a+|\frac{\delta f}{\delta b}|\Delta b+|\frac{\delta f}{\delta c}|\Delta c$$

The Relative Uncertainty: It signifies the proportion of the absolute uncertainty in relation to the mean value. Its expression is given as follows : $\Delta x/\bar{x}$

✎ *Remarque*

The measured value is written in the following form : $x=\bar{x}+\Delta x$

II Practical part

Calculating Error with Multiple Measurements - Intro to Physics

multiple measurement uncertainty

1. measure the mass and Density

Direct Measurement

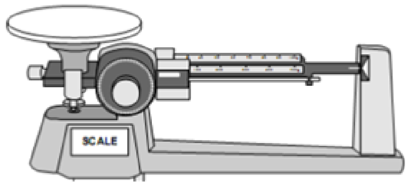

Figure 1: Steel ball & Balance

Choose a spherical object and measure the volume of an iron ball using a traditional scale multiple times. Write the results in the following tables :

N mesure	1	2	3	4	5	6
Masse(gr)	27,92	27,91	27,93	27,94	27,95	27,91

Questions :

1- Calculate the mean measured value. $\bar{m}$ = ***27.92***

2- Calculate the error mean absolute $\Delta\bar{m}$ = ***0.01***

3- Calculate the mean squared uncertainty σ=***0.017***

4- Calculate the absolute uncertainty and relative Δm= .....***0.03*** ....$\Delta m/\bar{m}$ =***0.00107***

5 - Write the measured value in the fom : m= $\bar{m}$±Δm; ....m=***27.92± 0.03***

1.1. Indirect Measurement

Choose a spherical object and measure its radius multiple times with a caliper. Write the results in the following tables:

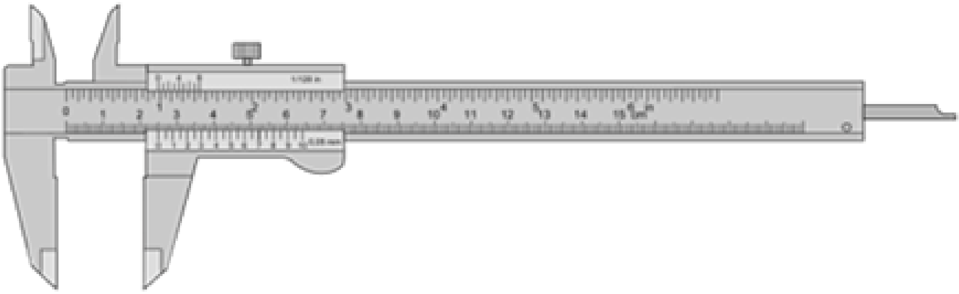

Figure 2: Caliper

N measure	1	2	3	4	5	6	7
Diameter	0,95	0,96	0,95	0,93	0,94	0,95	0,94
Volume	1,98	2	1,98	1,94	1,96	1,98	1,96
volumrtic ρ	14,1	13,96	14,1	14,39	14,24	14,1	14,24

Questions :

1- Calculate the mean measured value. $\bar{\rho}$ =***14.16***

2- Calculate the error mean absolute $\Delta\bar{\rho}$ =***0.11***

3- Calculate the mean squared uncertainty σ=***0.13***

4- Calculate the absolute uncertainty and relative $\bar{v}$ = ***1.97***..................Δv=***2***

5- gives the expressions of absolute uncertainty $\Delta\bar{\rho}$ as a function of v; m, Δv and Δm

$$\rho=\frac{m}{v}, \Delta\rho=\left|\frac{\delta\rho}{\delta m}\right|*\Delta m+\left|\frac{\delta\rho}{\delta v}\right|*\Delta v$$

6- Calculate the absolute uncertainty and relative Δρ= ***0.04***..........$\Delta\rho/\bar{\rho}$= ***0.002***

7 - Write the measured value in the fom : ρ = $\bar{\rho}$±Δρ; ρ = ***14.16±0.04***

Conclusion

Through the application of statistical methods, careful calibration, and consideration of systematic and random errors, can mitigate inaccuracies to a significant extent. By acknowledging and quantifying these uncertainties, we not only enhance the reliability of our findings but also foster a culture of transparency and rigor in scientific inquiry. Embracing uncertainty in measurements ultimately strengthens the foundation upon which further scientific advancements are built, ensuring that our conclusions are grounded in robust and dependable data.

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