General Article

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Errors in Scientific Physical Experiments

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INTRODUCTION

Error in a scientific measurement usually does not mean mistake or blunder. Instead, the terms "errors" and "uncertainly" both refer to unavoidable impression in measurements. No measurement of any sort is complete without a consideration of this inherent error. we cannot avoid the "uncertainties" by being very careful. So how do we deal with the measurement errors? All we can do is to try to ensure they are as small as possible and have a reliable estimate of how large they are. many instrumental, physical and human limitations cause measurement to deviate from the True values of the quantities being measured. These deviations are called "experimental uncertainties", but more commonly the shorter word error is used.

The true value of measured quantity is the value we would measure if somehow eliminated all errors from instrument and procedure. This is an ideal concept. We can improve the measurement process, of course, but since we can never hope to measure true values. when we specify the error in quantity. This estimate if far more than guess, for it is founded in a physical analysis of the measurement process and mathematical only of the equations which apply to the instruments and to the physical being studied. A measuring instrument measures some quality The smallest value that can be measured by measuring instrument correctly is called least count.

The least count puts limit on the accuracy of the measuring instrument. As a result, some error creeps into the observation. This error is known as permissible error of the instrument. It is equal to half of the least count. Besides this permissible errors, error may arise during calculation of the physical quantities using physical formula due to operations like addition, Subtraction, multiplication, division etc. and are called errors in calculation. That is the why it is important for students to learn how to determine quantitative estimate of the nature and size

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of experimental errors and to predict how these errors affect the reliability of the final result. So the process of the revaluating error associated with result of any measurement of quantity is called error analyze.

Indeterminate Errors (Random errors)

The name "indeterminate" indicates that there is no way to determine the size or sign of the error in any individual measurement. Indeterminate errors cause a measuring process to give different values when that measurement is repeated many times. The causes of these errors may be operator's error or biases, fluctuating experimental conditions, varying environmental conditions, and inherent variability of measuring instruments. The effect of these errors have on results can be somewhat reduced by taking repeated measurements then calculating their average. The average is generally considered to be a better representation of the "True Value" than any can single measurement because error of +'ve and -'ve sign tend to compensate each other in the averaging process.

Determinate (sor Systematic) Errors

When the measurement of a quantity is repeated several times, the error has the same size and algebraic sign for every measurement then the errors are called determinate or systemic errors. Determinate means the size and sign of the errors are determinable. The common cause of determinate error is miscalibrated scale or instrument, a colorblind observer uses of incorrect value of constant in equations reading, a scale incorrectly etc. Determinate errors can be more serious than indeterminate errors for three reasons.

There is no sure method for discovering and identifying them just looking at the experimental data. Their effects cannot be reduced by averaging repeated measurement. There is no possibility for positive and negative errors to reduce them. After the uncertainly in measurement is decide and the measurement is made, two common methods follow, namely (i)typically that measurement is repeated and then the individual measured value or, (ii) the measured value is combined mathematically with other measured values, either via combining equation or vice curve fit and graphical analysis to find the final measured value is then typically compared to an accepted value or otherwise known value in order to evaluate the relevance of your experimental results. A discussion of why the final measured value differs from the accepted or known value is called error analysis. There are two common comparison methods, called percent error and percent difference defined as

$$\% \text{ Error} = \left[\frac{|\text{ accepted value}|-|\text{experimental value}|}{|\text{accepted value}|} \right] \times 100\%$$

The % error is used when comparing the final measured value to well-accepted or well-known value.

$$\% \text{ difference} = \left[|(\text{value})-(\text{value2}) \right],$$

$$\% \text{ Error} = \left[\frac{\text{Observed value} - \text{True Value}}{\text{True Value}} \right] \times 100\%$$

The percent difference is used when comparing a measured value. Once the percent error or percent difference is known, the error analysis may proceed. There are two main contributing factors accounting for the discrepancy between the final measured value and known value. They are accuracy and precision.

Accuracy and Precision

Accuracy is the degree of measurement between the experimental value and true value. Good accuracy means the reading or the mean of the set of readings is very close to the true value and is associated with small systematic uncertainties. But, precise measurement is the degree of agreement among a series of measurements of the same quantity. Good precision means the readings are mostly very close to their mean value and is associated with small random errors.

Reporting and Use Uncertainties

We have seen that the correct way to state the result of measurement is to give a best estimate of the quantity and the range with in which we are confident the quantity lies. For example, the measurement of time recorded is usually reported as follows:

Best Estimate Time - 3.4 S

Probable range=- 3.35 to 3.5 S

Here, the best estimate lies at the midpoint of the estimated range of probable values 33 810 3.5 8. It allows the results of the measurement to be expressed in compact form. For eg, the above measurement of time is usually stated as follows

Measured Value of Time = (3.4±0.1)[5]

This single equation is equivalent to two statements:

(0) The measured value either may 0.1 S more than the best estimate or (ii) it may be 0.1 s less than the best estimate.

In general, the result of any measurement of a quantity x is stated as:

Measured Value of ∞ = X_{best} Sx

This statement means, first, that the experimenter's best estimate for the quantity concerned is the number X_{best}, and second, that he or she is reasonably confident the quantity lies somewhere between As-Sr and X_{best}+Sx For convenience the uncertainly Sx is always defined to be positive, so that X_{best}+ Sx is always highest probable value of the measured quantity and X_{best}-Sx the lowest.

Significant Figures

Several basic rules for stating uncertainties are worth emphasizing. First, because the quantity St is an estimate of an uncertainty, obviously it should not be stated with too much precision. If we measure the acceleration due to gravity g. it would be absured to state the result like:

(Measured g) = 9.82 ±0.02385 m/s^2

The digits measured accurately by the instrument in a particular measurement is called its significant figure. The greater the no. of significant figures obtained, the more accurate is the measurement. For eg. a meter scale cannot measure a distance less than 1 cm. A meter scale thus can make a measurement of 45 cm or 47 cm but not 46.5 cm. Therefore, 45 cm or 47 cm are the significant in the measurement of length.

Rules to Find out Significant Figures

1. All non-zero digits are significant. For eg. 6825 kg has four significant figures.
2. The zero between two non-zero digits are significant. For eg. 301m has three significant figures.
3. All zeros to the right of decimal point are significant if they are not followed by non-zero digits. For eg 21.00 Hz has four significant figures.
4. All zeros to the right of decimal pint and left to a non-zero digit are not significant For eg. 0.0320 has three significant figures.
5. All zeros to the right of the last non-digit are not significant. For eg . 4200 has two significant figures.

In high precision work, uncertainties are sometimes started with two significant figures but the experimental uncertainties should be 0.02 m/s^2

Rounding off: The dropping out of last insignificant digit is called rounding off.

Rules to Rounding off a Number :

1. The previous digit in a number remains unchanged after rounding off if the last insignificant digit it less than five. For eg.20.9m.
2. The previous digit in a number is increased by one after rounding off if the last insignificant digit is greater than five .Eg. 23.57cm 23.6cm.
3. If the last significant digit is exactly five, the previous digit is increased by one if it is odd and remains as such if it is even. For eg.20.95 21m 20.85

Rule for Staining Answers

The last significant figure in any stated answer should usually of the order of magnitude (in same decimal position) as the uncertainly.

Discrepancy

If two measurements of the same quantity disagree, we say there is a discrepancy. Numerically, we define the discrepancy between two measurement as their difference. Discrepancy = Difference between two measured values of the same quantity.

Fractional Uncertainly:

The uncertainly sx in the measurement of quantity x by itself does not tell hole story .So, the quantity of a measurement is indicated not just by the certainly sx but also by the ratio of Sx to X_{best} which leads us to fractional uncertainly.

: Fractional uncertainly often called relative uncertainly= Sx/xbest

This may perhaps the definition of Fractional uncertain. What is its role in your current work ?

Common Sources of Error in Physics Laboratory Experiments

Careful description of sources of error allows future experiments to improve on our techniques. This long list of common sources of error , this list may help. This list goes from the common to the obscure.

Incomplete Definition (may be systematic or random)

One reasons that it is impossible to make exact measurement is that the measurement is that the measurement is not always clearly defined. For example, if two different people measure the length of the same rope, they would probably get different results because each person may stretch the rope with a different tension. The best way to minimize definition errors is to carefully consider and specify the conditions that could affect the measurement.

Environmental Factors (Systematic or Random)

Be aware of errors introduced by our immediate working environment. We may need to take account for or protect our experiment from vibrations, drafts, changes in temperature, electronic noise or others effects from nearby apparatus.

Instrument Resolution (Random)

All instruments have finite precision that limits the ability to resolve small measurement differences, for instance, a meter scale cannot distinguish distances to a precision such better than about half of its smallest scale division (0.5 mm in this scale). One of the best ways to obtain more precise measurements is to use a null difference method instead of measuring a quantity directly. Null or balance methods involve using instrumentation to measure the difference between two similar quantities, one of which is known very accurately and is adjustable. The adjustable reference quantity is varied until the difference is reduced to magnitude of the unknown quantity can be found by comparison with the reference sample with this method, problems of source instability are eliminated, and the measuring instrument can be very sensitive and does not even need a scale.

Failure to Calibrate or check zero of instrument (Systematic): Whenever possible, the calibration of an instrument should be checked before taking data. If a calibration standard is not available, the accuracy of the instrument should be checked by comparing with another instrument that is at least as precise, or by consulting the technical data provided by the manufacturer. When making a measurement with a micrometer, electronic balance, or an electrical meter, always check the zero reading first. Re-zero the instrument if possible, or measure the displacement of the zero reading from the true zero and correct any measurements accordingly. It is a good idea to check the zero reading throughout the experiment.

Physical Variations (Random)

It is always wise to obtain multiple measurements over the entire range being investigated. Doing so often reveals variations that might otherwise go undetected. If desired. these variations may be cause for closer examination, or they may be cause for closer examination, or they may be combined to find an average value.

Parallax (Systematic or Random)

This error can occur whenever there is same distance between the measuring scale and the indicator used to obtain a measurement. If the observer's eye is not squarely aligned with the pointer and scale, the reading may be too high or low (some analog meters have mirrors to help with this alignment)

Instrument Drift (Systematic): Most electronic instruments have reading that drift over time. The amount of drift is. generally, not a concern but occasionally this source of errors can be significant and should be considered.

Lag time and Hysteresis (Systematic): Some measuring devices require time to reach equilibrium, and taking a measurement before the instrument is stable will result in a measurement that is generally too low. The most common example is taking temperature reading with a thermometer that has not reached thermal with a thermometer that has not reached thermal equilibrium with its environment. A Similar effect is hysteresis where the instrument readings lag behind and appear to have a “memory” effect as data are taken sequentially making up or down through a range of value Hysteresis is most commonly associated with materials that become magnetized when a changing magnetic field is applied.

Absolute Error

Absolute error is a measure of how far “off” a measurement is from a true value or an indication of the uncertainty in measurement. For example, if we measure the width of a book using a ruler with millimeter marks, the best we can do is to measure the width of the book to t the nearest millimeters. We measure the book and find id to be 75mm. We report the absolute error as 75mmt Imm. The absolute error is Imm. Note that absolute error is reported in the same units as the measurement. Alternatively, we may have a known or calculated value and we want to use absolute error to express how close our measurement is to the ideal value. Here absolute error is expected as the difference between the expected and actual values.

Absolute Error-Actual value - Measured Value