Physics 1

Measuring and measuring accuracy

Quantity (=suure)

- Quality of particle or material that can be measured
- Quantity= numerical value * unit

  - Example: speed = 90 km/h; length = 285,4 m; time = 0,4 s

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Measuring and accuracy

There is **uncertainty** associated with every measurement, and the Uncertainty arises from different sources:

- the limited accuracy of every measuring instrument,
- when reading the instrument,
- the measuring instrument is affecting the circumstances,
- marking errors etc.

NOTICE

- the result of a measurement is an approximation.
- if you measure the value of the quantity many times,

you get a group of results, from where you can decide the most likely value for the unit.

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Error types when measuring

Rough error
Systematic error
Occasional error

NOTICE

- the result of a measurement is an approximation.
- if you measure the value of the quantity many times, you get a group of results, from where you can decide the most likely value for the unit.

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Calculations in Physics

All the measuring results are approximations (not ”exact”), so we must approximate the answers with certain rules.

The rules are different in the cases where we have just adding/substracting or also multipliying/dividing in the formula.

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Definition

Significant numbers (merkitsevät numerot)

- All numbers are significant except
  - zeros at the end of an integer (mostly)
  - Zeros at the beginning of a decimal number

- **Examples**

  Tell the Amount of Significant Numbers

7,60 s	100,0g
0,0867 m	200 MB
100g	$1{,}51 \cdot 10^6$ m

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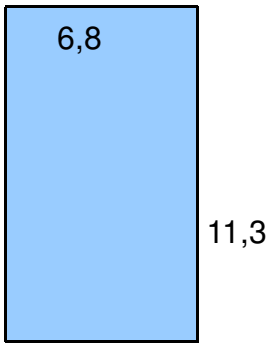
Digits in calculations

When making measurements, or when doing calculations, you should avoid the temptation to keep more digits in the final answer than is justified (or allowed).



Multiplying and dividing

Example:

The area of rectangle (These are measuring results!)

Length=6,8cm A_1=6,7x11,2=75,04

Height=11.3 cm

Area A= 76,84 cm^2 A_2=6,9x11,4=78,66

The real area is between 75,04 and 78,66, so you cannot use the precision of 0,01cm^2. The best answer should be 77cm^2 and the uncertainty is 2 cm^2 . The two digits must be dropped, because those are not significant digits. In scientific writing the answer would be (77±2)cm^2.

The final result of multiplication or division should have only as many digits as the number with the least number of significant figures (numbers) used in the calculation.

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Digits in calculations

Adding and subtracting

Example:

Measuring results of length are 2,5cm, 7,56 cm and 3,6 cm. The sum is 13,66 cm but it is not right to use the accuracy of 0,01. At the end of calculation you must approximate the result to 13,7cm.

The final result cannot be more accurate than the least accurate number used. Here we count the least accurate number with decimals (how many numbers is after decimal point).

The final result of addition or subtraction should have only as many digits after the decimal point as the number with the least number of digits after decimal point used in the calculation.

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Measuring devices for length

Historical:
Scale (weight)
Ruler, Caliper ruler (length, thickness)
Micrometer screw (thickness)
Modern:
Laser (length)
Ultrahigh sound (thickness)

and for time

Stopwatch vs. Lightports

Examples Measuring of length
Measuring of time

Q Is possible to make the uncertainty of the measurement smaller?

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Measured quantity x can be given in form

$$x = x_m \pm \Delta x$$

where

x_m= result of measurement

Δx= absolute error due to the used device (uncertainty)

The accurate result of the measurement is between

$x_m + \Delta x$ and $x_m - \Delta x$.

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- **Example 1** Is the diamond yours?

  A Friend asks you to borrow your precious diamond for a day to show her family. You are a bit worried so you carefully have your diamond weighted on a scale which reads **8,17g**. The scale's accuracy is claimed to be **±0,05g**. The **next day you weigh** the returned diamond again, getting **8,09g**. Is it your diamond?

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Error analysis in experiments

1. Mathematical analysis with the average deviation
   - Count the average value of measuring results
   - Count the absolute deviation of each measuring result AND with these count the Average absolute deviation
   - The result with errorlimits is then

     AVERAGE VALUE +-AVERAGE absolute DEVIATION

2. Verbal Analysis of the uncertainty
   - the limited accuracy of every measuring instrument, when reading the instrument, the measuring instrument is affecting the circumstances, marking errors etc.