PHY 107
Measurement

Mohammad Murshed
Department of Math and Physics

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Motivation

We conduct experiments to find out actual values of quantities.
During an experiment, we need data **which are basically measurements** in order to get results.
CLOCKS: timing
GPS: Locating coordinates

Base Quantities

Base quantities are those that are basic and mutually independent.
Base Quantities: length (m), mass(kg), time (s), electric current(A), temperature (K), amount of substance(mol), luminous intensity (cd)
Derived Quantities: Quantities that are derived from the base quantities
e.g. area (m^2), density (kg/m^3)

Scientific Notation

Used to express the very large and very small quantities by powers of 10

$3560000000\ m = 3.56\ X\ 10^9 m$

$0.000000492\ s = 4.92\ X\ 10^{-7} s$

On computers: 3.56E9, 4.92E-7

E: Exponent of 10

Prefix

To represent any very large or small measurement e.g.
$1.27X10^9 W = 1.27 gigawatt = 1.27 GW$

Factor	Prefix	Symbol
10^{-3}	*milli*	m
10^{-6}	*micro*	μ

Changing Units

CHAIN-LINK Conversion: Multiply the original measurement by a conversion factor (a ratio of units that is equal to unity)

$\frac{1\ min}{60\ s} = 1$, $\frac{60\ s}{1\ min} = 1$

2 min $=$2 min (1) $=$2 $min\ \frac{60\ s}{1\ min} = 120\ s$

Example: Write 25000 cm^3 in m^3

$1\ m\ =\ 100\ cm$

$(1\ m)^3\ =\ (100\ cm)^3$

$1^3\ m^3\ =\ 100^3\ cm^3$

Implies: $1\ cm^3\ =\ \frac{1}{100^3}\ m^3$

$25000\ cm^3\ =\ \frac{25000}{100^3}\ m^3 = 0.025\ m^3$

Length and Time

Length

1m is the length of path traveled by light in vacuum in $\frac{1}{299792458}s$

e.g. Radius of Earth is about $6\ X\ 10^6 m$

Time

Time has two things to consider:

1. When did it happen?
2. How long?

For example: Age of the universe: $5\ X\ 10^{17} s$

1 s is the time taken by 9192631770 oscillations of the light emitted by a cesium 133 atom

Mass, Volume and Density

Quantities mass and volume can be used to define density
Density is mass per unit volume
$\rho = \frac{m}{V}$
$\rho_{water} = 1 \frac{g}{cm^3}$

Dimensional Analysis

Dimension denotes the physical nature of a quantity
mass:M, length: L, time:T
[ ]: dimension
$[vel] = \frac{L}{T}$
$[area] = L^2$
Problem: A car starts from rest and moves with constant acceleration (a) as time(t) passes. What is the relationship between the position of the car (x), acceleration (a) of the car and time(t)?

Dimensional Analysis

a prop. to x^(p) t^(q)

[x]=L=L^(1)=L^(1)T^(0)

[a]=L/T^(2)

[t]=T

Soln:

$x \propto a^n t^m$

$L^1 T^0 \propto (\frac{L}{T^2})^n T^m$

$L^1 T^0 \propto L^n T^{m-2n}$

n=1, m-2n=0, m=2

$x \propto at^2$

$x = kat^2$

x prop. to a^(n) t^(m)

Significant Figures

1. All non-zero digits are considered significant e,g, 91 has 2 significant figures, 123.45 has 5 s.f
2. Zeros appearing anywhere between 2 non-zero digits are significant e.g 101.1203 has 7 s.f.
3. Leading zeros are NOT significant e.g. 0.00052 has 2 s.f.
4. Trailing zeros in a number containing a decimal point are significant e.g 12.2300 has 6 s.f

The same number will have different significant figures based on the format...

12.2300

1.0030

N	Significant figures
1200	2
1200.00	6
$1.200\ X\ 10^3$	4

12.2301

10030

Accuracy and Precision

Precision : Describes how close measurements are to each other.
e.g. measuring the mass of an object in kg
EXP 1: 2.3, 2.28, 2.29, 2.31
EXP 2: 2.3, 2.7,2,2.5
EXP 1 measurements are PRECISE
Accuracy: Defines how close the measured value is to the true (actual) value
e.g. finding the value of g (acceleration due to gravity)
true value: 9.81 $\frac{m}{s^2}$
EXP 1: 9.4 $\frac{m}{s^2}$
EXP 2: 9.85 $\frac{m}{s^2}$
EXP 2 measurement is more accurate

Sample Standard Deviation

It refers to the deviation of an observed value from the mean of the observations in the sample

{1,5,6}

Assume that a sample contains N observations :$x_1, x_2, x_3, ..., x_N$

N=3;

$$s = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \overline{x})^2}{N-1}}$$

xb=(1+5+6)/3

xb=4;

s: standard deviation

N: Number of observations in the sample

$x_1, x_2, ...$: observations

$\overline{x}$: mean value of these observations

Example: The set (1.3,1.7) has a smaller deviation from the mean compared to the set (1,2)

s=sqrt(((1-4)^(2)+(5-4)^(2)+(6-4)^(2))/2)

Reference

Fundamentals of Physics by Halliday and Resnick