

PHY 107

Measurement

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OUTLINE

- ▶ Motivation
- ▶ Base Quantities and Units
- ▶ Scientific Notation
- ▶ Prefix
- ▶ Changing Units
- ▶ Length and Time
- ▶ Density
- ▶ Dimensional Analysis
- ▶ Order of Magnitude
- ▶ Significant Figures
- ▶ Accuracy and Precision

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

$$3560000000 \text{ m} = 3.56 \times 10^9 \text{ m}$$

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

On computers: 3.56E9, 4.92E-7

E: Exponent of 10

Prefix

To represent any very large or small measurement e.g.
 $1.27 \times 10^9 W = 1.27 \text{ gigawatt} = 1.27 GW$

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)

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

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

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 $6 \times 10^6 m$

Time

Time has two things to consider:

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

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

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

$$\rho = \frac{m}{V}$$

$$\rho_{\text{water}} = 1 \frac{\text{g}}{\text{cm}^3}$$

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

Soln:

$$x \propto a^n t^m$$

$$L^1 T^0 = \left(\frac{L}{T^2}\right)^n T^m$$

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

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

$$x \propto at^2$$

$$x = kat^2$$

Order of Magnitude

There are several definitions, but the following is one of them...

Order of magnitude is the smallest power of 10 used to represent that number

$$N = a \times 10^b; \text{ b=order of magnitude; } \frac{\sqrt{10}}{10} \leq a < \sqrt{10}$$

N		Order of Magnitude
0.2	2×10^{-1}	-1
1	1×10^0	0
5	0.5×10^1	1

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...

N	Significant figures
1200	2
1200.00	6
1.200×10^3	4

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, 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

Reference

Fundamentals of Physics by Halliday and Resnick