BASIC PHYSICS 1

Chapter 1
Physics Quantities, Unit and Measurement

Vira Rahayu, M.Si

Department of Physics

Faculty of Mathematic and Sains

Billfath University

TOPICS:

- Measurement
- Definition of Physics Quantities and Units
- Scientific Notation and Units Convertion
- Significant Figure

Measurement

- To be quantitative in Physics requires measurements
- How tall is Ming Yao? How about his weight?
  - Height: 2.29 m (7 ft 6 in)
  - Weight: 141 kg (310 lb)

- Number + Unit
  - “thickness is 10.” has no physical meaning
  - Both numbers and units necessary for any meaningful physical quantities

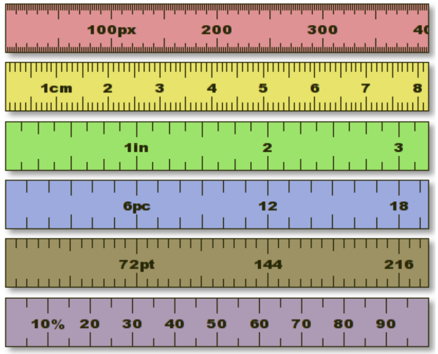
Type Quantities

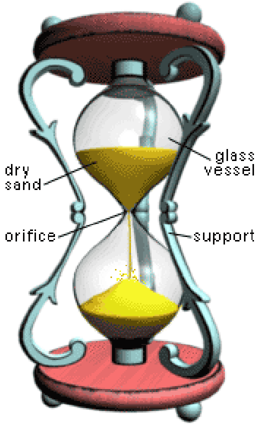
- Many things can be measured: distance, speed, energy, time, force ……
- These are related to one another: speed = distance / time
- Choose three basic quantities (DIMENSIONS):
  - LENGTH
  - MASS
  - TIME
- Define other units in terms of these.

SI Unit for 3 Basic Quantities

- Many possible choices for units of Length, Mass, Time (e.g. Yao is 2.29 m or 7 ft 6 in)
- In 1960, standards bodies control and define Système Internationale (SI) unit as,

  - LENGTH: Meter
  - MASS: Kilogram
  - TIME: Second





UNITS

- Physical quantities have units!
- Example: Unit of length
  - In the Middle ages many kingdoms had different definitions of a foot, etc.
  - Inch, foot, meter, mile, light-year …
- Today in science/engineering, the SI system of units.

  Three basic units in mechanics:
  - Length: Meter (Based on the speed of light: length of path traveled by light in 1/299,792,458s)
  - Mass: kg (Platinum cylinder in International Bureau of Weights and Measures, Paris)
  - Time: s (Time required for 9,192,631,770 periods of radiation emitted by cesium atoms.)
- There are 7 basic units

  (including other branches of physics).

SI UNITS

SI Base quantities		
Length	meter	m
Time	second	s
Mass	kilogram	kg
Electric Current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

PREFIXES In UNITS

- Prefix is a specifier or mnemonic that is prepended to units of measurement to indicate multiplies or fraction of the units.
- Depending on the scale one often likes to use prefixes.
- Example, for length it is convenient to use km = 1000 m when traveling by car,

  or nm=10^{-9} m when discussing molecular scale objects.

Table 1-1 Prefixes for Powers of 10*

Multiple	Prefix	Abbreviation
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

* The prefixes hecto (h), deka (da) and deci (d) are not multiples of 10^3 or 10^{-3} and are rarely used. The other prefix that is not a multiple of 10^3 or 10^{-3} is centi (c). The prefixes frequently used in this book are printed in red. Note that all prefix abbreviations for multiples 10^6 and higher are uppercase letters, all others are lowercase letters.

SCIENTIFIC NOTATION

To express the very large and very small quantities we often run into in physics, we use *scientific notation, which employs powers of 10.*

Example :

- 3560000000 m = 3.56 X 109 m
- 0.000000492 s = 4.92 X 10-7 s.

Multiplication	When multiplying two numbers, the exponents are added.
Division	When dividing two numbers, the exponents are subtracted.
Raising to a power	When a number containing an exponent is itself raised to a power, the exponents are multiplied.

EXAMPLE (SCIENTIFIC NOTATION)

In 12 g of carbon, there are NA = 6.02 X 1023 carbon atoms (Avogadro'S number). If you could count 1 atom per second, how long would it take to count the atoms in 1 g of carbon? Express your answer in years.

PICTURE THE PROBLEM We need to find the total number of atoms to be counted, N, and then use the fact that the number counted equals the counting rate R multiplied by the time t.

1. The time is related to the total number of atoms N, and the rate of counting $R = 1$ atom/s:

$$t = \frac{N}{R}$$

2. Find the number of carbon atoms in 1 gram:

$$N = \frac{6.02 \times 10^{23}\ \text{atoms}}{12\ \text{g}} \times 1\ \text{g} = 5.02 \times 10^{22}\ \text{atoms}$$

3. Calculate the number of seconds it takes to count these at 1 per second:

$$t = \frac{N}{R} = \frac{5.02 \times 10^{22}\ \text{atoms}}{1\ \text{atom/s}} = 5.02 \times 10^{22}\ \text{s}$$

4. Calculate the number of seconds in a year:

$$n = \frac{365\ \text{d}}{1\ \text{y}} \times \frac{24\ \text{h}}{1\ \text{d}} \times \frac{3600\ \text{s}}{1\ \text{h}} = 3.15 \times 10^{7}\ \text{s/y}$$

5. Use the conversion factor 3.15×10^7 s/y (a handy quantity to remember) to convert the answer in step 3 to years:

$$t = 5.02 \times 10^{22}\ \text{s} \times \frac{1\ \text{y}}{3.15 \times 10^{7}\ \text{s}}$$

$$= \frac{5.02}{3.15} \times 10^{22-7}\ \text{y} = \boxed{1.59 \times 10^{15}\ \text{y}}$$

REMARKS The time required is about 100,000 times the age of the universe.

EXERCISE If you divided the task so that each person counted different atoms, how long would it take for 5 billion (5×10^9) people to count the atoms in 1 g of carbon? (*Answer* 3.19×10^5 y)

CONVERSION

- Conversions between units are very important.
  The use of different units has again and again led to errors,
  sometimes with bad consequences in engineering and science
  (and homework/exams), but it is easy to avoid.
  1 mile = 1.609 km, 1 hr = 3600 s, 1 tonne = 1000 kg ...
- Avoid skipping the units
  (for example, to save your writing time ?)
  - Are all the ingredients for a problem in the same units system?
    It is crucial to perform the conversion, BEFORE doing any algebra.
  - Basic SI units are always safe
    It is OK to use km or nm, but don't mix them!
- We will expect you to give results with appropriate units,
  in homework, exams, etc. as part of the correct answer!

EXAMPLE (CONVERSION)

Your employer sends you on a trip to a foreign country where the road signs give distances in kilometers and the automobile speedometers are calibrated in kilometers per hour. If you drive 90 km/h, how fast are you going in meters per second and in miles per hour?

PICTURE THE PROBLEM We use the facts that 1000 m = 1 km, 60 s = 1 min, and 60 min = 1 h to convert to meters per second. The quantity 90 km/h is multiplied by a set of conversion factors each having the value 1, so the value of the speed is not changed. To convert to miles per hour, we use the conversion factor (1 mi)/(1.61 km) = 1.

1. Multiply 90 km/h by a set of conversion factors that convert km to m and h to s:

$$\frac{90\ \cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\ \text{m}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{60\ \cancel{\text{min}}} \times \frac{1\ \cancel{\text{min}}}{60\ \text{s}} = \boxed{25\ \text{m/s}}$$

2. Multiply 90 km/h by 1 mi/1.61 km:

$$\frac{90\ \cancel{\text{km}}}{\text{h}} \times \frac{1\ \text{mi}}{1.61\ \cancel{\text{km}}} = \boxed{55.9\ \text{mi/h}}$$

Derived quantities and dimensions

Table 1-2 Dimensions of Physical Quantities

Quantity	Symbol	Dimension
Area	A	L^2
Volume	V	L^3
Speed	v	L/T
Acceleration	a	L/T^2
Force	F	ML/T^2
Pressure (F/A)	p	M/LT^2
Density (M/V)	ρ	M/L^3
Energy	E	ML^2/T^2
Power (E/T)	P	ML^2/T^3

m^2
m^3
m/s
m/s^2
$N=kg \bullet m/s^2$
$N/m^2=kg/m \bullet s^2$
kg/m^3
…

Dimensional analysis can give you a check/answer

Example

The pressure in a fluid in motion depends on its density p and its speed v. Find a simple combination of density and speed that gives the correct dimensions of pressure.

Hint!

Quantity	Symbol	Dimension
Area	A	L^2
Volume	V	L^3
Speed	v	L/T
Acceleration	a	L/T^2
Force	F	ML/T^2
Pressure (F/A)	p	M/LT^2
Density (M/V)	ρ	M/L^3
Energy	E	ML^2/T^2
Power (E/T)	P	ML^2/T^3

The pressure in a fluid in motion depends on its density ρ and its speed v. Find a simple combination of density and speed that gives the correct dimensions of pressure.

PICTURE THE PROBLEM We note from Table 1-2 that both pressure and density have units of mass in the numerator, whereas speed does not contain M. We therefore divide the units of pressure by those of density and inspect the result.

1. Divide the units of pressure by those of density:

$$\frac{[p]}{[\rho]} = \frac{M(L/T^2)}{M/L^3} = \frac{L^2}{T^2}$$

2. By inspection, we note that the result has dimensions of v^2. The dimensions of pressure are thus the same as the dimensions of density times speed squared:

$$[p] = [\rho][v^2] = \frac{M}{L^3}\left(\frac{L}{T}\right)^2 = \boxed{\frac{M}{LT^2}}$$

REMARKS When we study fluids in motion in Chapter 13, we will see from Bernoulli's law that for a fluid moving at a constant height, $p + \frac{1}{2}\rho v^2$ is constant where p is the pressure in the fluid.

SIGNIFICANT FIGURES

- A significant figure is one that is reliably known
- All non-zero digits are significant (123.456)
- Zeros are significant when
  - between other non-zero digits (100002)
  - after a non-zero digit AND

    BEFORE or AFTER the decimal point (100. and 1.00)
  - can be clarified by using scientific notation
- Multiplication and division The number of significant figures in the result of multiplication or division is no greater than the least number of significant figures in any of the numbers.
- Addition and subtraction The result of addition or subtraction of two numbers has no significant figures beyond the last decimal place where both of the original numbers had significant figures.

EXAMPLE (SIGNIFICANT FIGURES)

Find the sum of 1.040 and 0.21342.

PICTURE THE PROBLEM The first number, 1.040, has only three significant figures beyond the decimal point, whereas the second, 0.21342 has five. According to the rule stated above, the sum can have only three significant figures beyond the decimal point.

Sum the numbers, keeping only three digits beyond the decimal point: $1.040 + 0.21342 = \boxed{1.253}$