General

Physics # 108136

INTRODUCTION

Physics and Measurement

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Outline

- Physical Quantity
- Measurement of a Physical Quantity
- The Value of a physical Quantity
- Classification of Physical Quantities
- Dimension
- Units and System of Units
- Orders of Magnitude
- Dimensional Analysis
- Unit Conversion
- Uncertainty and Significant Figures

Physical Quantity

What is a physical quantity?

By Prof. Rashad Badran

❑ A Physical Quantity:

➢ Any number used to describe a physical phenomenon, body or substance quantitatively. This number can be obtained by measurement and can be used in the mathematical equations of science and technology.

Example: A person measured the height of a building as 20 m. The number 20 represents the magnitude (the result of measurement of length). Here m (meter) refers to the unit which gives a meaning to the number.

i.e. The value of the physical quantity (height) = [Numerical value (20)][unit (m)]

Measurement

What is a measurement?

- A measurement:
  - is a direct or an indirect expression of a certain quantity with a suitable standard or unit of measurement. Thus a measuring device is needed, here, and must be calibrated and has standard units

  - The value of a physical quantity, which is the quantitative expression of a certain physical quantity, is the product of a number (numerical value) and a unit. Thus the numerical value of the height (20) depends on the units (meters) in which it is expressed. If the units are changed to centimeters then the number obviously becomes 2000. (1 meter = 100 centimeters)

Section 1.1 Classification of Physical Quantities

There are two types of physical quantities:

- Fundamental physical quantities (***e.g.*** Length, L, Mass, M and Time, T (in this course)). They are called Standards (or base quantities).

- Other physical quantities: Those can be expressed in terms of the fundamental physical quantities (or standards), ***e.g.*** velocity (v), acceleration (a), force ($F = m\,a$), momentum ($p = m\,v$), kinetic energy ($K = m\,v^2/2$),….,.etc.)

Dimension: Physical nature of a quantity

- Dimension can be expressed in terms of the three fundamental physical quantities which are called standards:
  - Length → L ;
  - Mass → M;
  - Time → T

- ***e.g.*** Physical nature of a distance is length L no matter whether the distance is measured in meters or inches, *i.e.* [Distance] = L

- Dimensions of other physical quantities: area [A], volume [V], velocity [v], acceleration [a], force [F], …etc can be expressed in terms of the standards L, M, and T which have their units as meter, kilogram and second, respectively. Since the velocity is simply defined as distance/time, the dimension of velocity is:

$$\text{Dimension} \equiv [v] = L/T$$

Dimension: Physical nature of a quantity

- What is the dimension of acceleration a ?

Answer: Since acceleration is defined as: velocity/time

$\therefore$ $[a]$= [velocity]/[time]

But dimension of velocity is $[v]$ =L/T and dimension of time is [time]=T

Thus the dimension of acceleration is :

$$[a] = \frac{L/T}{T} = \frac{L}{T^2}$$

Dimension: Physical nature of a quantity

- What is the dimension of force F?

Answer: Since force is defined as: (mass)*(acceleration)

$\therefore$ [F]= [mass]*[acceleration]

But dimension of mass is [mass] = M and the dimension of acceleration is found as: [a] = L/T^2

Thus the dimension of force is : [F] = M L/T^2

Units and Systems of Units

- A **Unit**
  - is a special physical quantity which is defined and adopted by convention, with which other particular quantities of the same type are compared to express their value. e.g. kg, *m*, c*m*, foot, second,..etc
.

- Two Well-Known **Systems of Units**:

✓**International System** which is abbreviated as **SI** (French name)

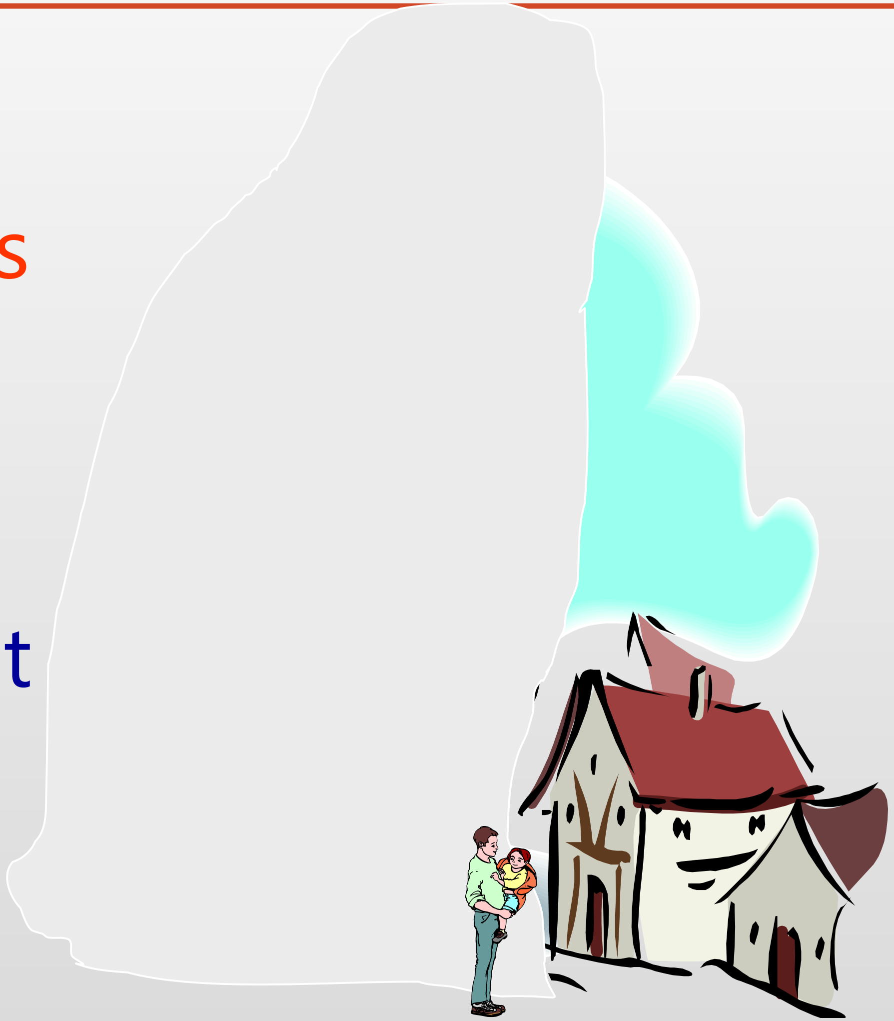
e.g Units: kg for mass, meter for distance and second for time

✓**The British System**

e.g Units: Slug for mass, foot for distance and second for time

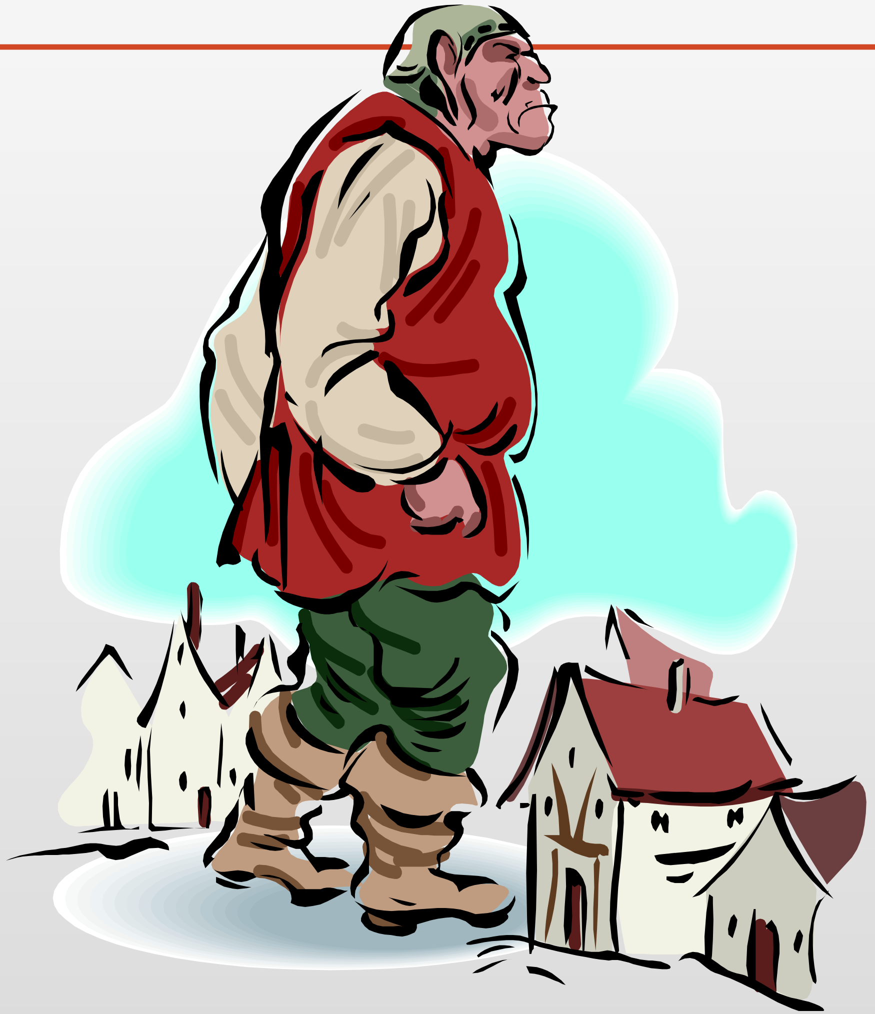
Units Standards

- When we say "This house is big"
  - Person 1: "Yes, it is big".



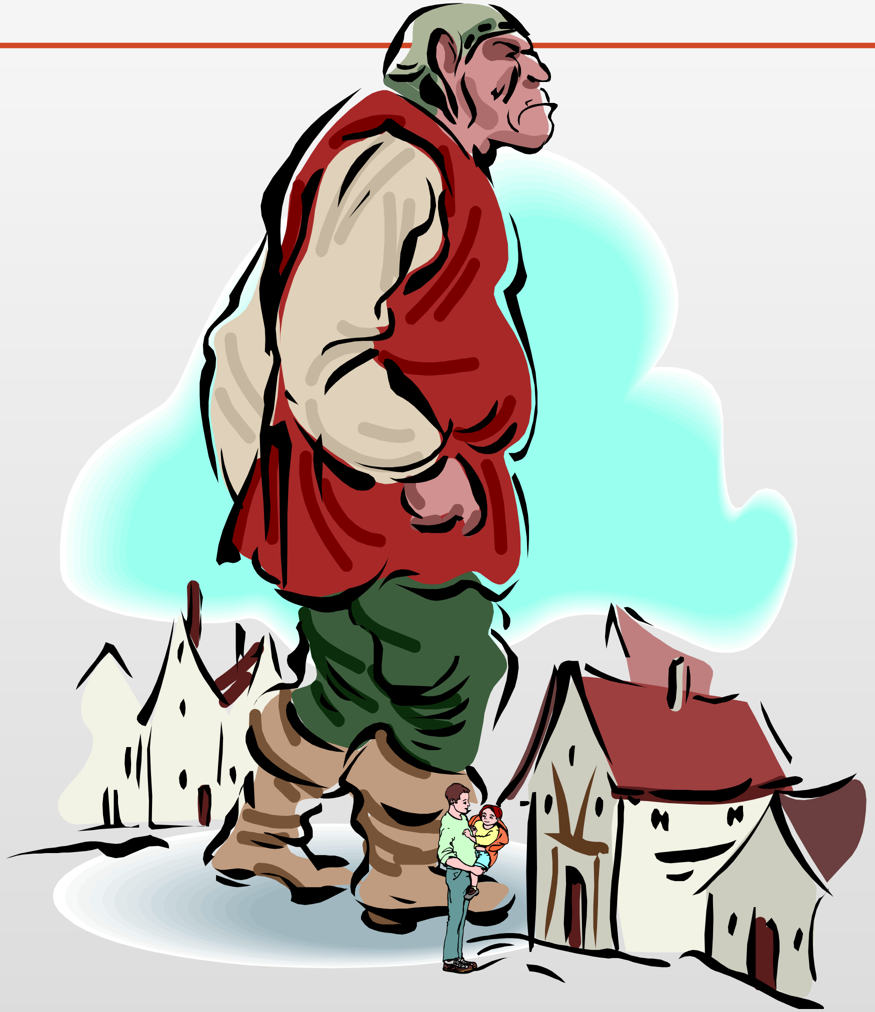
Units Standards

- When we say "This house is big"
  - Person 2: "No, it is not a big house".



Units Standards

- Which one is correct?
- We need a standard that every body agrees upon.



Note: Units of standards L, M, and T can also be used to specify dimension.

Units Standards

- Thus the dimensions found in terms of L, M, and T can also be written as:

$$[\text{Distance}] = m$$

$$[v] = m/\text{s}$$

$$[a] = m/\text{s}^2$$

$$[F] = \text{kg}.\ m/\text{s}^2$$

Note: Units of standards L, M, and T are meter, kg and second, respectively, in **SI** system.

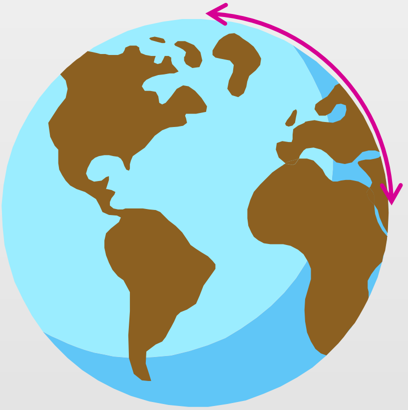
SI Units: Time, T

- **Second:**
  - Previously defined as a fraction of the mean solar day
  - Currently defined to be the time required for 9,192,631,770 cycles of wavelength of a transition in cesium atom

SI Units: Length, L

❑ Meter:

- Previously defined as one ten-millionth of the distance between the North Pole and the equator.

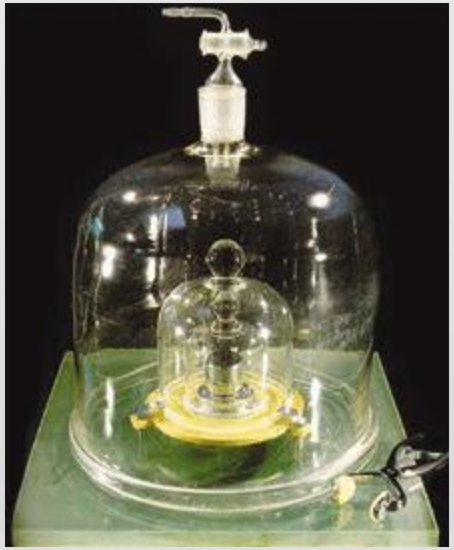


- Currently defined to be the distance that light travels in a vacuum in 1/2,99,792,458 of a second

SI Units: Mass, M

Kilogram:

- Defined as the mass of a particular cylinder of Platinum-Iridium alloy. (old definition;abandoned)
- Defined in terms of the Plank constant, $h=6.626 \times 10^{-34}$ kg m^2s^{-1},with researchers are able to make precise mass measurement using equipment such as Kibble balance. (recent definition)



Other Fundamental quantities and SI Units

- **Temperature**: Units of K
- **Electric Current**: Units of A
- **Luminous Intensity**: Units of Candela
- **Amount of Substance**: Units of Mole

Note: SI system of units is used by most people and will be used in this course.

Units and Dimensions

Example

Your height is 180. What is the dimension of this height? *i.e.* [height]=?

a) Second

b) Kg

c) L

d) Slug

e) Pound

Units and Dimensions

Example

The height of a building is measured to be 10 *meters*. What is the dimension of this building?

a) *cm*

b) *m*

c) *Foot*

d) *Slug*

e) *Kg*

Unit Prefix

deka-	da	10^{1}
hecta-	h	10^{2}
kilo-	k	10^{3}
mega-	M	10^{6}
giga-	G	10^{9}
tera-	T	10^{12}

deci-	d	10^{-1}
centi-	c	10^{-2}
milli-	m	10^{-3}
mircro-	μ	10^{-6}
nano-	n	10^{-9}
pico-	p	10^{-12}

Unit Prefix: Length

1 nanometer = 1 nm = 10^{-9} m (atomic size)

1 micrometer = 1 μm = 10^{-6} m (bacteria)

1 millimeter = 1 mm = 10^{-3} m (pin head)

1 centimeter = 1 cm = 10^{-2} m (finger)

1 kilometer = 1 km = 10^{3} m (University ring)

Orders of Magnitude: Powers of Ten

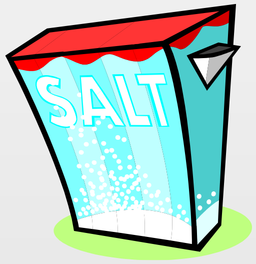
- **Order of magnitude**: The order of magnitude of a certain quantity is the power of ten of the number that describes this quantity.

- *e.g. for* $x = 10$, the quantity x has one order of magnitude.

- *e.g. for* $x = 10^3$ then x has three orders of magnitude

Unit Prefix: Mass

1 microgram = 1 μg = 10^{-6} g (dust particle)



1 milligram = 1 mg = 10^{-3} g (grain of salt)

1 gram = 1 g = 10^{-3} kg (paper clip)

Unit Prefix: Time

1 nanosecond = 1 ns = 10^{-9} s

(time for light to travel 0.3 m)

1 microsecond = 1 μs = 10^{-6} s

(space shuttle to travel 8 mm)

1 millisecond = 1 ms = 10^{-3} s

Units: The British System

✓Used in a few countries.

- Length: 1 $inch$ = 2.54 cm; 1 ft =0.3048 m; 12 $inch$ = 1 ft; 1 $yard$= 0.914 m
- Force: 1 $pound$ (ℓb) = 4.45 $Newtons$
- Mass: 1 $slug$ = 14.59 Kg; 1 Kg $=2.205$ ℓb

Note: Use the conversion factors in the appendix of your textbook