Units of Measurement in 3 easy points

Here we stand to that first step towards understanding physics. The first step is units of measurements.

We cover (i) Need for units;
(ii) SI units;
(iii) Length, Mass and Time

Need for units

Different countries had different units, they still do. There was the FPS (Foot, Pound, Second), CGS (Centimetre, Gram, Second) and MKS(Meter, Kilogram, Second) system of units. This made comparison of various experimental data difficult. So, all the scientist got together in 1971 in a conference called General Conference on Weights and Measures held in **France** and adopted an International System of Unit for scientific, technical, industrial and commercial work. It was called **SI units** [short for *Système Internationale d' Unites* in French]

- Measurement of any physical quantity involves comparison with an internationally accepted reference standard called **unit**.
- Units are of two types, fundamental or base units and derived units.
- The units for the fundamental or base quantities are called **fundamental** or **base units**.
- When units are expressed as combinations of the base units, such units are called **derived units**.
- A complete set of both the base units and derived units, is known as the **system of units**.

SI units

- In SI units, there are seven fundamental units called Length, Mass, Time, Electric Current, Thermodynamic Temperature, Amount of Substance and Luminous Intensity.
- Besides the seven base units, there are two more units that are defined for (i) plane angle and (ii) solid angle. These two have units called radian and steradian respectively.
- The unit of Length is called **metre** (m). The metre is the length of the path travelled by light in vacuum during a time interval of 1/299,792,458 of a second. Just of give an idea, light travel 299,792,458 metres in one second.
- The unit of Mass is **kilogram** (kg). The kilogram is equal to the mass of the international prototype of the kilogram (a platinum-iridium alloy cylinder) kept at international Bureau of Weights and Measures, at Sevres, near Paris, France.

Units of Measurement in 3 easy points

- The unit of Time is **second** (s). The second is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom.

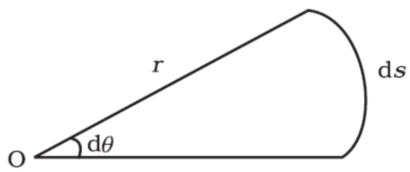
- The unit of Electric Current is **ampere** (A). The ampere is that constant current which, if maintained in current two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length.

- The unit of Thermodynamic Temperature is kelvin(K). The kelvin, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

- The unit of Amount of Substance is **mole** (mol). The mole is the amount of substance of a system, which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon - 12.

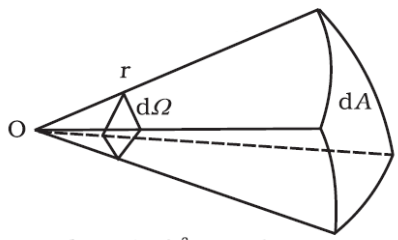
- The unit of Luminous Intensity is **candela** (cd). The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of of 1/683 watt per steradian.

- Plane angle dθ as the ratio of length of *arc d*s to the radius r.



$d\theta = ds/r$ radian

- Solid angle dΩ as the ratio of the intercepted area *d*A of the spherical surface, described about the apex O as the centre, to the square of its radius r



$d\Omega = dA/r^2$ steradian

- Derived units are a combination of fundamental units. Let's take speed. Speed is Distance upon Time or m/s. **m** being unit of length (ie distance) and **s** being the unit of time. Therefore m/s or speed is a derived unit as it is made up from combination of fundamental unit. Many derived units exist, which we will revisit when we take up DIMENSIONAL ANALYSIS.

Length, Mass and Time

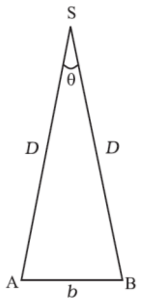
Our use of unit will mostly be limited to Length, Mass and Time. So let's explore these 3 units is detail

Length

- There are large distances and small distances. By large distance we mean distance between Earth and Moon or inter-planetary distances. By small distances we mean diameter of molecules, atoms or fundamental particles like electrons, protons and neutrons.

- **Large distances** are measured by a method called the **Parallax method**. To give an example watch the stationary index of your right hand with right eye closed. Then close both the eyes and open only the right eye. The index finger appears to have moved, whereas, it has been stationary all along. This apparent movement is termed as parallax, stationary objects appear to change position.

  (i) The key to Parallax Method is this figure:



  (ii) We know the angle θ measured in radians is given by the equation $\theta = \frac{b}{D}$. Suppose A and B are two point on Earth and 'S' lies on a distant star, whose distance we want to measure from Earth. As the distance between Earth and Star (D) is very large in comparison to the distance between AB points(b), therefore for all practical purposes AB can be treated as a straight line. There for the distance between Earth and star is given by:

$$D = \frac{b}{\theta}$$

  D and b are measured in SI units of Length and θ is measured in radians.

  (iii) We know a complete circle is 360°. But 1° (1 degree) = 60′ (60 minutes). And further 1′ (1 minute) = 60″ (60 seconds). Now let's convert degrees to radians. We know

$$360° = 2\pi \text{ radians.}$$
$$1° \text{ (1 degree)} = 2\pi/360° \text{ radians} = 1.745 \times 10^{-2} \text{ rad}$$

  (iv) As the distance between Earth and Star is very large, the angle is in the range of seconds. Just remember that.

- **Small distances**: A simple method would be estimating the molecular size of oleic acid. We choose Oleic acid has it has large molecular size of the order of 10^{-9} m. The method is like this:
  (i) We take a known volume of the Acid

  (ii) We spread the acid on a non-absorbing surface and keep on spreading till we can spread it no more. Then we calculate the area.

  (iii) We divide the Volume of the Acid by Area of Spread, we will have the diameter off the molecule.
  Diameter of Acid molecule $= \frac{\text{Volume of the Acid}}{\text{Area spread of the Acid}}$

- The smallest distances are measured in Fermi [1 fermi = 1 f = 10^{-15} m] and very large distances are measured in parsec [1 parsec = 3.08×10^{16} m].

Mass

- Mass is a basic property of matter. It does not depend on the temperature, pressure or location of the object in space.

- SI unit of Mass, the kilogram (kg) is inconvenient while measuring atomic size particles. For measuring atomic size particles, we use **unified atomic mass unit** (u):

$$1u = (1/12) \text{ of the mass of an atom of carbon-12 isotope}$$
$$1u = 1.66 \times 10^{-27} \text{ kg}$$

- The masses of the objects vary over a very wide range. There is tiny mass like that of electron of the order of 10^{-30} kg and huge mass of about 10^{55} kg of the known universe.

Time

- We use an atomic standard of time, which is based on the periodic vibrations produced in a cesium atom. This is also called atomic clock.

- The cesium atomic clocks are very accurate. Atomic Clocks lose or gain no more than 3 μs in one year.

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