

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

“Measurements” - Then and Now’

Dr.(Prof.) V.C.A. NAIR*

Educational Physicist, Research Guide for Physics at JJT University, Rajasthan, India.

ABSTRACT: The paper begins with a philosophical approach to measurements. Various types of measurements in the past and present are extensively dealt with. Different systems of units with more stress on the System International Units. Definitions of units in the SI. Supplementary units and derived units. A brief account of Error, Accuracy, Precision and Uncertainty. There is a chronicle of measurements and discoveries during the last two centuries. The paper is exhaustive and the author has covered almost all aspects of ‘measurements’ and the reader will (I hope) find it more a treatise than a simple treatment. More additions are due to the vast experience in teaching Applied Physics of the author. The paper ends with a Conclusion

KEYWORDS: Accuracy, Base units, Cesium Clock, Counting, Customary units, Derived units, Elephant Water Clock, Large Hadron Collider, Macroscopic and Microscopic Measurements, Precision, SI Units, Supplementary Units, Systems of Units, Uncertainty.

I. INTRODUCTION

1.1 The Philosophy of Measurement:

“Measurement” is a noun the dictionary meaning of which is “Act of measuring”, that is measuring any physical quantity or any other thing.

Physics could be distinguished from other sciences by the part played by it in measurement. Other sciences measure some of the properties which they investigate but it is generally recognized that when they make such measurements, they are always depending directly or indirectly on the results of Physics. All fundamental measurements belong to Physics, which might almost be described as the science of measurement. Coming to application, according to author, A.H. Cook of Royal Astronomical Society, London, “*Measurement is the ‘nervous system’ of technical life*”. It has long been known that a natural science has been converted into an exact study of nature through measurement. Progress is also impossible in applied science without measurement. The idea of leading role of measurement in Physics has been established in scientific thought since the days of Galileo. The entire history of natural science and philosophy witnesses to the mounting significance of mensuration in the development of human culture and scientific understanding. The thinkers of antiquity and Leonardo da Vinci, Descartes, Newton, Leibniz, Kant, Hegel, Gauss, Helmholtz, Mendeleev, Einstein Bohr and many more a profound analysis of fundamental aspects of the problems arising, development of the theory of mensuration and its logical foundation.

There is a saying that “*It is easier to make measurements than to know what you are measuring*”. Measurements cannot be reduced to the simple procedure of just ‘look’ and ‘see’, recoding the reading of a measuring device by proper observation. This implies ‘reading’ as a record of ‘observation’. In this respect, Henri Lebesgue (1875-1941) [] is certainly right when, speaking about the measurement of geometric quantities, he draws attention to the fact that though “*a geometrical measurement begins physically....., it is only achieved metaphysically*”. This statement is valid, for all other measurements as well. It should be noted that no physical theory can ignore the need to link its mathematical apparatus up with the readings of experimental devices.

According to Omelyanovsky [8], Mensuration is a cognitive process in which information is obtained through experiment on the numerical value of a measured quantity. The following constituents are included in the process of measurement: i) the quantity measured, ii) the unit of measurement, iii) the observer and the measuring instruments, iv) methods of measurement and v) the result of measurement. The objects of Physics are studied in experiments and in the final analysis should be perceived either by sense organs or in a mediated way, through the readings of the instruments. A necessary premise of the cognition of nature in Physics therefore is that, in taking both the quantitative and qualitative character of physical quantities into account it finds the correspondence between the empirical data and the quantitative determination (numbers). The establishment of the correspondence is sometimes called ‘measurement’.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

Measurement differs from the so-called arithmetisation and from a general point called quantitative ranking. The arithmetisation of a certain class of properties of things is the establishing of rules by which it is possible to determine from the property of a class a number (or a certain set of numbers) corresponding to it, and from a certain number (or set of numbers) to determine the quantity corresponding to it. If, for instance, one ascribes a pair of numbers to each point in a plane, according to certain rule (each pair of numbers corresponding to one point and one point on the plane), one thereby arithmetises the plane (since each point on it possesses the property of having a certain point on it)

If the properties of a certain class are such that it is possible to employ the concepts 'bigger' or 'smaller', they are called intensities (or intensive quantities). If this class is arithmetised in such a way that a higher intensity corresponds to a bigger number, then the arithmetisation is 'quantitative ranking'. To make a simple example, a liquid A is denser than a liquid B can be represented by writing $A > B$ or $B < A$. The arithmetisation of a class of intensities (e.g. a class of lengths, volume, electrical resistance, mass, etc.) is 'Measurement'. A measurement can be expressed in the form:

$$Q = q [Q]$$

which is the basic equation of measurement. Here Q is the measured quantity and $[Q]$ the unit of measurement and q is a real number. $q [Q]$ is the result of measurement. From a methodological point of view, measurement can be divided into direct and indirect measurements. In direct measurement, the result is obtained from the act of measuring the quantity itself independently of measuring the other quantities. In indirect measurement, the result is obtained in terms of direct measurement of quantities that are connected with the measured one by a certain mathematically expressed dependence.

The standard form of measurement is developed from simpler ones. The initial form is the random or individual form of measurement, whose specific feature is that a certain kind of quantity, characterizing one thing, is measured by means of any other single thing characterized by the same kind of quantity. For example, if write $A = b$ things B (the equal sign means equal with respect to such and such property).

II. CUSTOMARY UNITS

2.1 The Ancient Methods:

The individual form of measurement is only met in the early historical stages of development of production and human culture. In the early years customary units were widely used. For example, in Babylonia there were three separate, unconnected groups of measures of length which had arisen independently of one another; one based on the 'cubit' [a finger's breadth digit, span and cubit, which measured short intervals; one based on the 'gar' (approximately equal to 6 meters)] and a third group – the 'mile', an hour's walk measure long distances. The cubit is a linear measure used by many ancient and medieval people. 1 cubit = 18 inches (457 mm) i.e the length of the arm from the elbow to the tip of the middle finger which is equivalent to 6 palms or 2 spans.

In the contemporary Physics, the origin of the system of units starts from the International Bureau of Standards at Sevres a suburb of Paris, France (Fig.1) which was established on 20 May 1875. All the standard quantities of measurements are preserved here. One of the oldest is the English units of measurement wherein the units of length were compared to various parts of the human body. This is because in the olden days people knowing something were few and people knowing nothing were many. They considered the king of the land or some standard person appointed by the King having proper height and physique was chosen for measurements. A 'foot' is taken as the length between heel

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017



Fig.1 The International Bureau of Standards at Sevres, Paris
(One can see the standard meter bar at the bottom right)

and toe of that standard man (Fig. 2) and equal to 12 inches. The 'yard' is the distance between the nose and palm of that person and equal to 36 inches. A 'span' is the length between the thumb and little finger when the palm is spread and equal to 9 inches. The thumb width is about an inch. A 'rod' is the distance between certain number of people standing in a line. There is no precision or accuracy involved in such measurements. I would like to mention an incident, though it appears to be out of context: In the second half of 17th century, when Isaac Newton wanted to send a letter from Cambridge to the Secretary of Royal Society in London which is about 50 miles distance, he would address it:

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

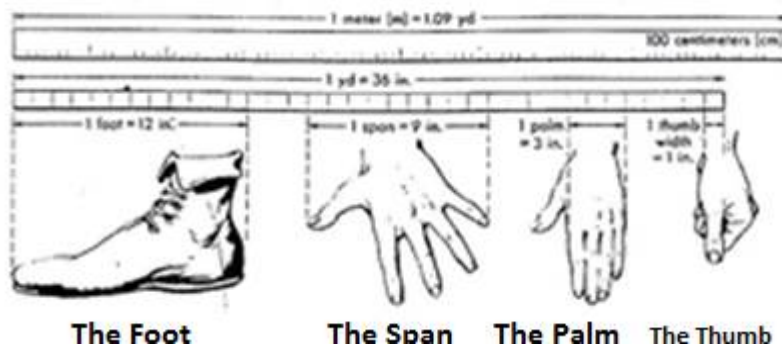
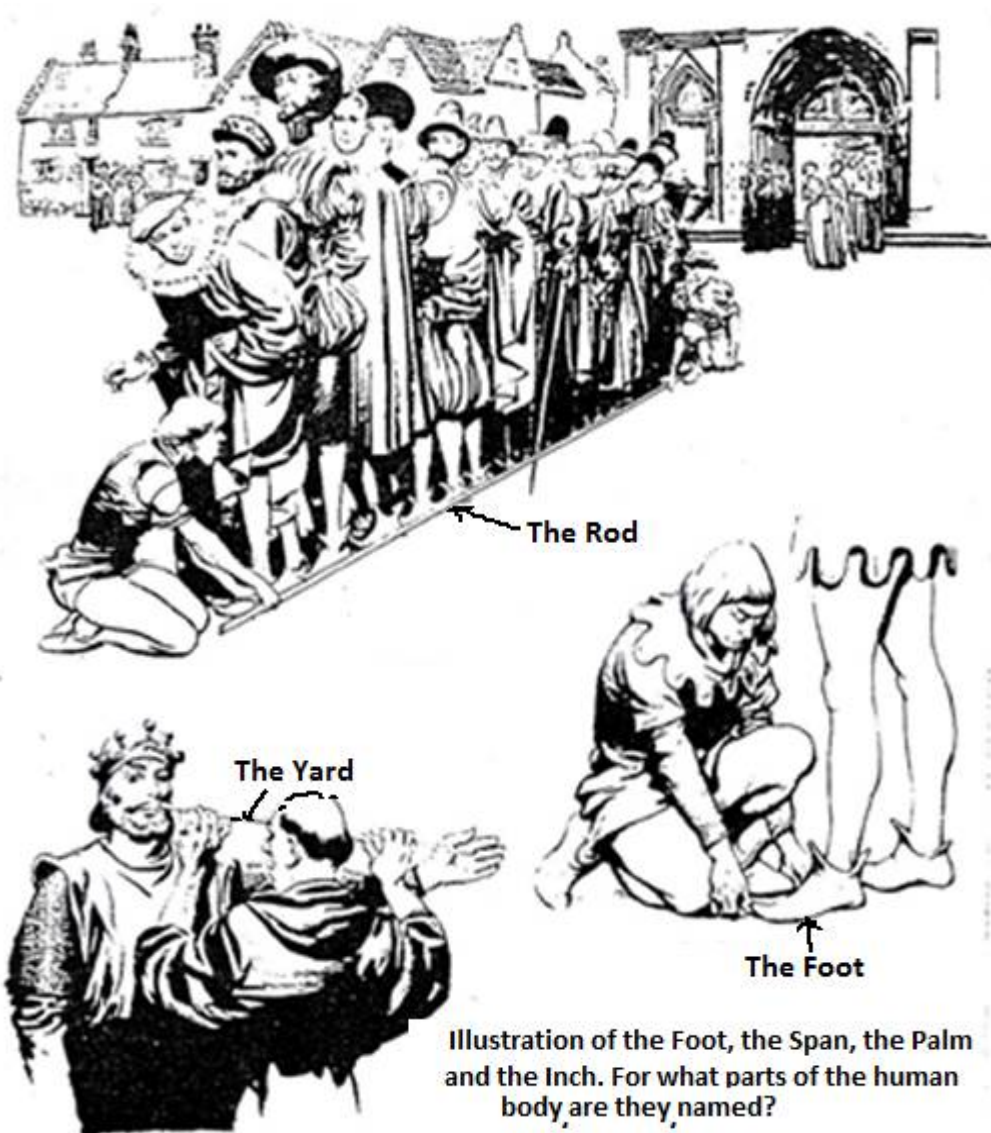


Fig.2 Ancient English units of length

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

“To Mr. Oldenburge at his house about themiddle of the old Palmail in St.Jameses Fields in Westminster.” No house number or post code, indeed not even a city name. Yet, the apparently vague address was considered sufficient for the purpose of correspondence before the development of London’s West End. The judgment of the distance 50 miles by people those days is certainly a part of measurement.

Saharan nomads, for whom the exact distance from one water hole to another may be a matter of life and death, have long employed an extraordinary variety of terms to describe measure for long distances. They reckon in terms of a stick’s throw or a bowshot, or the carrying distance of the voice, or the distance seen with naked eye from ground level, or from a camel’s back, or walking distance from sunrise to sunset, or from early morning, midmorning or late morning or a man’s walking distance with no load to carry, or with a laden ass or with an ox or walk across an easy or difficult terrain.

2.2 Counting:

A basic part of measurement and of ancient origin is ‘counting’. Any understanding (of course, of science and mathematics) requires background. For example, our present knowledge of non-linear differential equations or tensors require knowledge of calculus and simple differential equations. But, these cannot be studied without knowledge of algebra. What is essentially required to study algebra is knowledge of arithmetic. Before studying arithmetic, one should know ‘counting’. Counting is as old as Mathematics itself. Now-a-days counting which includes addition, subtraction or division are done by calculators. Simple counting is known even to the housewife. The oldest surviving example of counting are notched bones from the last ice age. The next oldest are the so-called ‘Clay tokens’ (Fig.3) [5] found during excavations in the Middle East dating from early 8000 BC to as late as 1500 BC. The earliest tokens are un-decorated and geometrically shaped spheres, discs, cones and so on while the later ones are often incised and shaped in more complex ways the purpose of which is unknown. A probable explanation is that they were counting units in accountancy. Different shapes are used for different entities, for example, a sheep from a flock, a specific

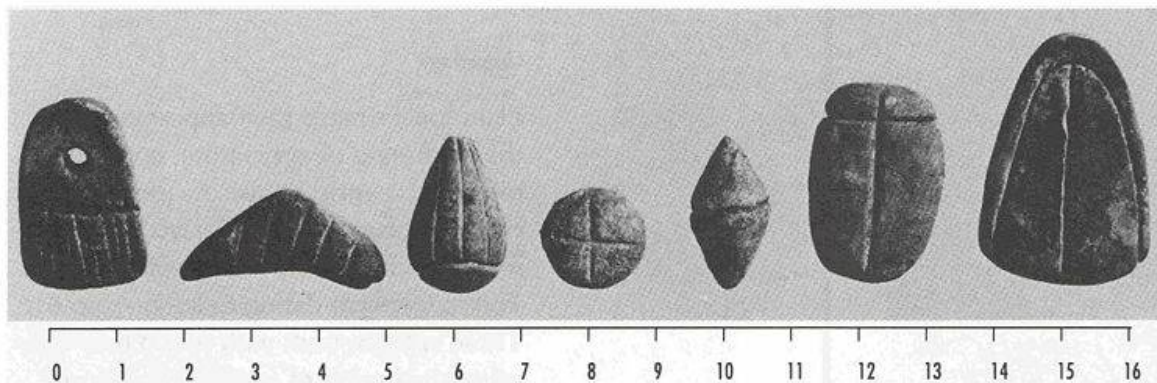


Fig.3 Clay tokens from the Middle East [5]

measure of a certain product, such as a bushel of grain. Accountancy motivated the development of all early systems and methods of counting.

Finger counting or *Dactylonomy* is the act of counting using ones fingers. The word is of Arabic origin the meaning of which is “*Number reckoning by finger folding*”. The finger symbols from a manual published in the year 1520 is shown in(Fig. 4) Our palm having 10 fingers is the reason for the decimal system. There are 36 different and unique positions of the fingers indicating a number next to it.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

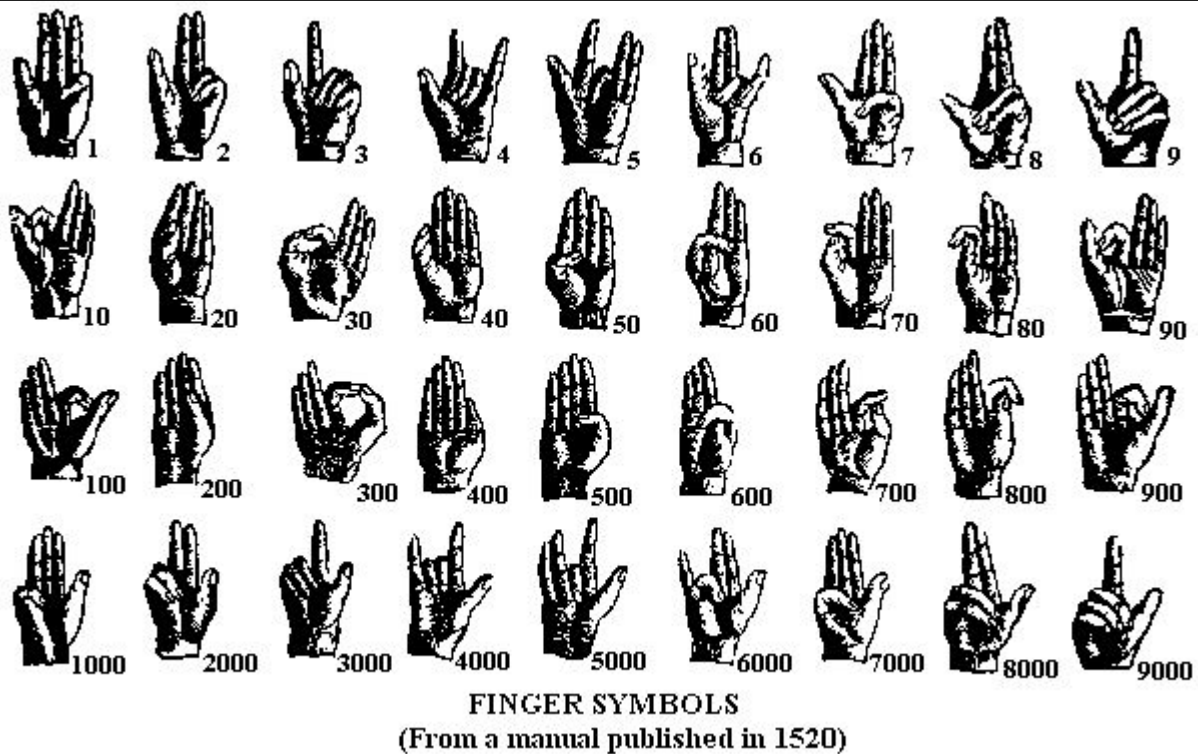


Fig.4 Finger symbols indicating numbers

2.3 Geometry:

A knowledge of geometry is a must for measurements. 'Geometry' literally measurements related with the Earth and it was the meaning given by the ancients till Rene Descartes (1596-1650) (Fig.5) the philosopher, mathematician and scientist invented the co-ordinate system and linked algebra with geometry. The inscription on the door of Plato's academy reads when translated, "No one



Fig.5 Rene Descartes (1596 – 1650)

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

ungeometrical should enter". The ancient Greeks undoubtedly revered the study of geometry. For them, 'geometry' means 'earth-measurement'. Geometry was of great practical importance prior to the classical period. Both geometry and arithmetic might have a common root in the techniques of surveying. Egyptian surveyors used a tightly stretched string as a ruler for drawing straight lines. A pivoted string was used as a compass for drawing circles. The pyramids of Egypt were built with perfect geometrical calculation. In the present day construction of buildings and skyscrapers what an architect or builder should look into is both 'geometry' and 'symmetry'. Symmetry is the general out look in comparison with the nearby objects that form a background. As a matter of philosophical and historical interest, I would like to give here some calculations done by ancient Egyptians on pyramids

The gradient of the inclines faces of pyramids depended on both the height and their apex and the length of their side. The hieroglyphic word for the gradient was 'skd', the meaning of which is 'ratio'. It was measured in palms (1 cubit = 7 palms) by dividing half the length of a side (in palms) by the height of the apex in cubits. A pyramid whose vertical height is $93\frac{1}{2}$ cubits and the side 140 cubits, we can find the skd as follows: Divide 140 by 2 to get half the length of the side, i.e. 70, then multiply by 7 to convert into palms. i.e. 490, then divide 490 by $93\frac{1}{2}$ to get the answer as $5\frac{1}{4}$ palms. As there were 4 finger's breadth in one palm, the final answer is given as 5 palms 1 finger's breadth.

In the olden days seeking direction also was of prime importance. The direction of North South was obtained by finding the direction the noonday Sun from a vertical pole set up in the sand as gnomon (the rod in the sundial). Then the path traversed by the tip of its shadow would be observed. Two points where this intersected, a suitable circle drawn around the gnomon, would be joined. Then that line was bisected to determine the direction of the Sun at midday. Finding the direction is of primary importance to sailors who use a magnetic compass in a well-protected place in their sailing boats. Anybody tampering with the compass is given a death penalty. (Fig.6) [11]



Fig.6 Form of nautical punishment including that for tampering with the Compass [11]

One of early earth measurements by ancient Greeks was to measure the circumference of the Earth. Three Greek thinkers, Ptolemy, Eratosthenes (276 BC-194BC) (Fig.7) and Hipparchus (190 BC-120 BC) (Fig.8) made important contributions in Earth measurements. In Fig. 10 is shown Hipparchus observing the heavens somewhere in Alexandria, Egypt. Eratosthenes became director of the library at Alexandria

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

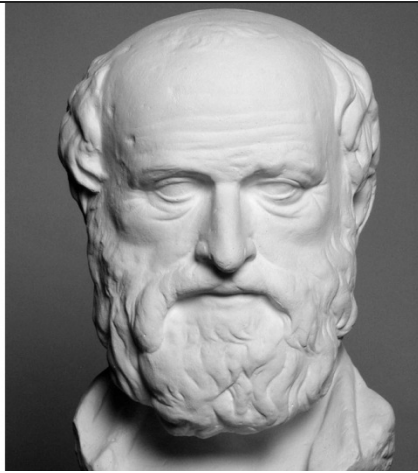


Fig.7 Eratosthenes (276BC-194 BC)



Fig.8 Hipparchus (190 BC-120 BC)

in 235 BC. He gave an accurate estimate of the Earth's circumference. It is said that he used well in far off Syene (Present Aswan in Egypt) and an obelisk in the ground of Alexandria library (Fig.9) on the day of observation when the Sun shone directly into the well leaving no shadow on its walls, he measured the angle created between the obelisk and its shadow. Since both places lie almost same meridian of longitude, the angle gives the difference in latitude between Syene and Alexandria

The angle at the center of the Earth subtended by the well and the obelisk must be equal to the angle of the shadow. As the Sun is far away, its rays can be taken as parallel at the Earth. The measured angle was 7.2° . Given the distance by camel from Alexandria to Syene, known to be about 5000 stadia, the circumference of the Earth could be calculated by multiplying 5000 by the ratio $360 : 7.2$ giving a circumference of 250,000 stadia. A modern conversion of the figure gives about 39,690 km which is very close to the current value of Earth's equatorial circumference 40,075 km.

The importance of measurement is stressed in a statement by the 19th Century Scots-Irish mathematical physicist, Lord Kelvin (1824-1907) on 6 May 1886. *"When you can measure what you are speaking about and express it in numbers, you know something about it, but when you cannot measure it in numbers, your knowledge is of a meager and unsatisfactory kind"*. Albert Einstein (1879-1955) the great mathematical astrophysicist wrote that *"Knowledge cannot spring from experience alone but only from a comparison or the intellect with the facts of observation"*.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

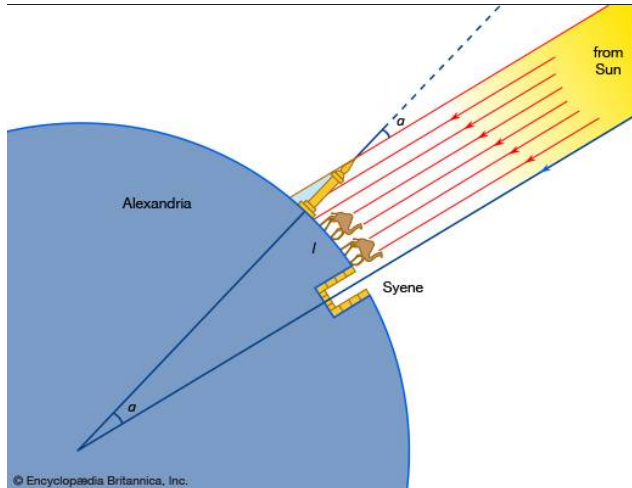


Fig. 9 Measurement of circumference of Earth by Eratosthenes

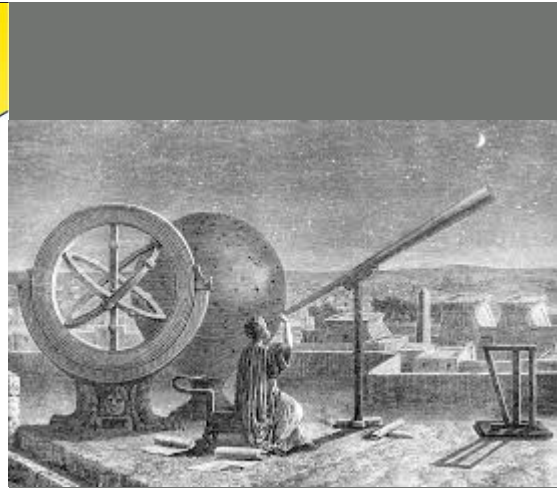


Fig.10 Hipparchus observing the Heavens somewhere in Rhodes of Alexandria, Egypt

III. TYPES OF MEASUREMENTS

3.0 There are basically two types of measurements: i) Macroscopic measurements and ii) Microscopic measurements. Here I would like to caution the reader that by the look of the word, 'microscopic', it has no connection with the optical instrument the microscope and a macroscope does not either exist.. Microscopic measurements are measurements that have dimensions of a micro (10^{-6}) or less.

3.1 Macroscopic Measurements: 'Macro' means large size and Macroscopic measurements are large-scale measurements such as radius of Earth (6370 km), height of an average man (1.7m), dimensions of a dust particle (~ a mm), Age of Earth (1.3×10^{17} s), time taken by a train (30 minutes), human heart beat (~0.8 s) mass of a bag of wheat (50kg), mass of a grain of iron dust (~1 mg), etc.

3.2 Microscopic Measurements: Microscopic measurements are those related to the atomic system such as atoms, molecules, ions, etc., for example, radius of an atom ($\sim 10^{-11}$ m), mass of an electron (9.11×10^{-31} kg, time taken by an electron to go once round the nucleus of hydrogen atom ($\sim 10^{-16}$ second). I have extensively dealt with the types of measurements in another research paper [6]

The distinction between two types of measurements will be made clear by taking Ohm's law as an example:

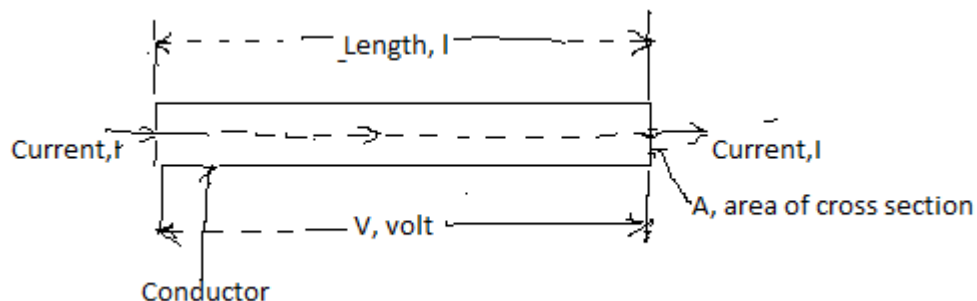


Fig.11 Illustration for verification of Ohm's Law

In the verification of Ohm's law experiment (Fig.11), we measure the potential difference V across a resistor of resistance R by a voltmeter and the current I flowing through it by an ammeter, so that the Ohm's law equation in the macroscopic form is $R = \frac{V}{I}$, where the resistance R of the conductor is assumed constant provided no physical change occurs in the material of the conductor. All quantities, V , I and R are all macroscopic quantities. Current I is a characteristic of a particular conductor. It is a macroscopic

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

quantity like the mass of an object, the volume of an object or the length of a rod. A related microscopic quantity for the current I is the current density \mathbf{J} which is a vector and is characteristic of a point inside a conductor rather than of the conductor as a whole. If $d\mathbf{s}$ is an element of surface area, then the current is given by the surface integral,

$$I = \mathbf{j} \cdot d\mathbf{s}$$

And carried out over any cross section, A . The potential difference, V is given by the integral,

$$V = - \int_a^b \mathbf{E} \cdot d\mathbf{l}$$

Where \mathbf{E} is the electric field between two arbitrary points a and b of the conductor. The negative sign indicates that the charge carriers act in opposition to the field \mathbf{E} . Now, dividing V and I and ignoring the negative sign we get,

$$R = \frac{V}{I} = \frac{\int \mathbf{E} \cdot d\mathbf{l}}{\int \mathbf{j} \cdot d\mathbf{s}} = \frac{E l}{j A} = \rho \left(\frac{l}{A} \right)$$

Thus, we got the resistivity ρ as the microscopic quantity for the resistance R . The macroscopic quantities V , I and R are of primary interest when we carry out electrical measurements on real conducting objects. Quantities V and I are read on meters. The microscopic quantities \mathbf{E} , \mathbf{j} and ρ are of primary importance when we are concerned with the fundamental behavior of matter rather than specimens of matter. They are also important when we deal with the interior behavior of irregularly shaped conducting objects

3.3 Is there any phenomenon the measurement of which is both macroscopic and microscopic?

Well! There is! The Brownian motion on which the famous scientist Albert Einstein and Smoluchowski worked on. In the year 1827, the botanist Robert Brown (1773-1858) watched the behavior of pollen grains suspended in water through a powerful magnifying glass. He found that the grains were in a state of continuous chaotic motion. It was shown independently in 1905 by Einstein (1879-1955) and Smoluchowski (1872-1917) that the Brownian particles behave like gigantic molecules whose average kinetic energy is equal to that of the liquid or gas surrounding the particles. In their theoretical treatment they have shown that a Brownian particle with a mass of $m \approx 10^{-14}$ kg and radius $r \approx 10^{-6}$ m is an object that is both macroscopic and microscopic at the same time. From the energy point of view it is microscopic because it participates in thermal motion and its average kinetic energy equals the average energy of thermal motion of the molecules, i.e. $\frac{3}{2} kT$ where k is Boltzmann's constant and T the absolute temperature. But, from the point of view of its momentum, the particle is macroscopic. Its linear momentum, $p = \sqrt{2mK} = \sqrt{2m \frac{3}{2} kT}$, where K is the kinetic energy. This is substantially larger than that of a molecule which is equal to $p_0 = \sqrt{2m_0 \frac{3}{2} kT}$. The ratio of the two linear momenta is,

$$\frac{p}{p_0} = \sqrt{\left(\frac{m}{m_0} \right)} \approx \sqrt{\left(\frac{10^{-14}}{10^{-26}} \right)} = \sqrt{(10^{12})} = 10^6$$

Naturally, the collision of a molecule with a Brownian particle resembles the collision of a completely elastic particle with a wall, the molecule bounces off the particle with practically the same velocity in the opposite direction and the momentum of the Brownian particle is changed by only a very small amount $\Delta p = 2p_0$. A very large number of such collisions will be required and the number can be found to be

$$N_0 \approx \frac{p}{p_0} = 10^6$$

The discovery by Robert Brown appeared very simple, but some of giants in Physics such as Einstein, Smoluchowski, Langevin, Uhlenbeck and many others have explained by rigorous mathematical treatment. Hence, without going further into such details, the time interval during which the particle travelling one 'step' is shown to be 10^{-4} second and the number of steps during an observation time of, say 15 minutes, is seen to be 10^7 . The treatment speaks for itself that Brownian motion is both macroscopic and microscopic.

The above treatment given by me is further augmented by excerpts from a very famous book [2]

"Brownian motion is a physical phenomenon of utmost importance, because it bridges a gap between microscopic and macroscopic worlds, very much as Boltzmann's equation does. It is good to see transition from microscopic to macroscopic dynamics at work".

In the present days of Nano-technology, measurements which were earlier thought to be microscopic have been made macroscopic.

By suitable arguments, the concept of 'Entropy' applied to a thermodynamic system can also be shown to be both macroscopic and microscopic.

In conclusive to this sub-topic, I would like to point out the essential difference between 'Physics' and 'Engineering'. In Engineering, we rarely use microscopic measurements whereas in Physics we use both macroscopic and microscopic measurements. For example, if somebody wants to find out the wavelength of light, it is mostly the work of a physicist and very rarely of an engineer.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

IV. TIME

4.0 There is a continuous uniform and universal flow of time. Past is systematically replaced by the present and future in a rhythmic fashion. Any amount of time cannot be stored or replaced. A man ages with time. What clocks and time keepers measure is the recurring cycles of motion. The measurement of time is essentially the comparison of one motion cycle with another, such as the rhythm of breathing, the revolution of the minute hand of a clock, the repetition of day and night, or woman's monthly period cycle. It is hard to say whether keeping time means social or natural measurements. Forgive me when I add, who keeps up time in the present days, one rarely finds a professor going to the class before the bell rings.

4.1 Elephant Water Clock: In Fig.12 is shown the principle of an elephant water clock. It is based on the 13th century drawing by Ibn al-Razzaz al-Jazari and a working model from Dubai. It depends on a water filled bucket concealed inside the elephant in which floats a deep bowl with a small hole in the center. The bowl takes exactly 30 minutes to fill through the hole. As it sinks, it pulls a string attached to a 'see-saw' in the tower which releases a ball that drops into the mouth of a snake. This causes the snake to tip forward while a system of strings makes the figure in the tower raise either his right or left hand and the mahout strike his drum, to mark the full or half hour. The snake now tips back again and as it does so, the sunken bowl is hauled up and the cycle begins again.

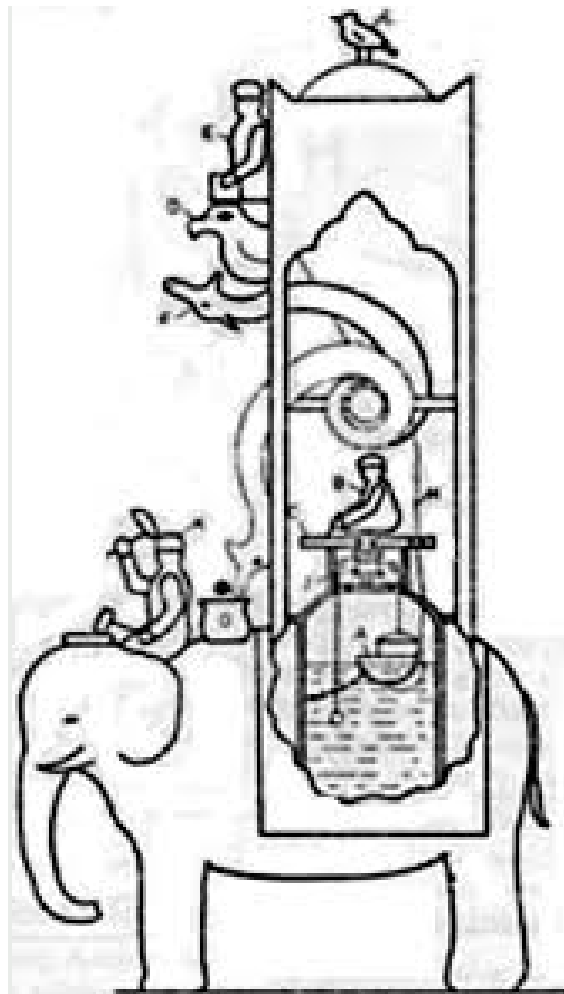


Fig.12 Principle of 13th century Elephant water Clock

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

4.2 Mechanical Clocks: Mechanical clocks date from the end of the 13th century and were driven by falling weights. The first public clock that struck the hours was erected in Milan, Italy in 1335, and the oldest surviving clock in England is the one at Salisbury Cathedral from 1386. These clocks were found to be erroneous. With the introduction of the pendulum mechanism by Christiaan Huygens (1629-1695) in the second half of the 17th century minute hands were introduced and later followed with seconds in the pendulum clocks for astronomical observations and in marine chronometers. During the 18th century the accuracy of the clocks improved from few seconds to $\frac{1}{5}$ th of a second per day. A French decimal clock marked both in Arabic and in Roman numerals is shown Fig.13. The first one is the earliest one in which only the hour is marked with numerals whereas in the second one, the minute hand is marked in the inner circle up to 100 because during the French revolution, a day was divided into 10 hours, each hour into 100 minutes and each minute into 100 seconds. The outer circle in the dial, however, shows 12 and 60 conforming with the present version. The older division was not accepted and the scientist Pierre-Simon Laplace (1749-1827) changed that system to the present one.

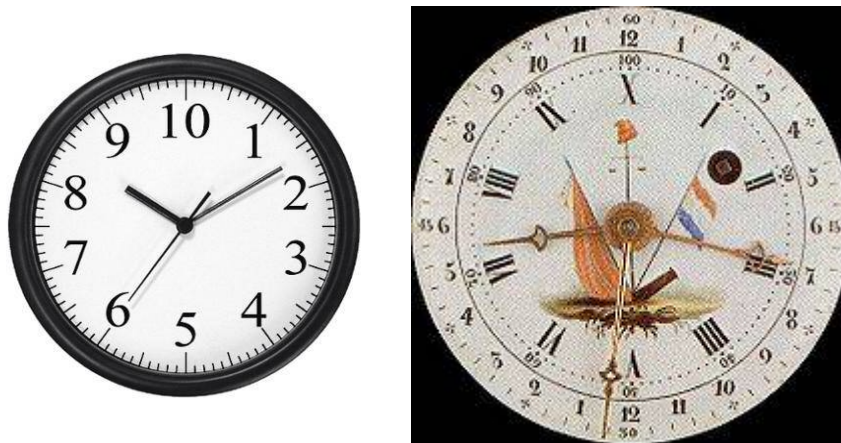


Fig.13 French Decimal Clocks with Arabic numerals and with Roman numerals

With the introduction of the digital clocks and the present atomic clocks (which I shall deal with later), the measurement of time has been the most precise as ever. Measurements in the past used to be precise and observers worked with lot of enthusiasm and interest.

V. MASS - WEIGHING

5 The mass of an object is a scalar representing the quantity of matter present in it whereas weighing is a process of finding the weight which is a force with which the mass is attracted towards the center of the Earth and hence is a vector and proportional to the mass of the object. The acceleration due to gravity being constant at a particular place on Earth, mass and weight can be synonymously used. I am dealing here with the process of weighing past and present to find the mass. There are two things, the instrument or device and the standard. The mass of an object is measured using a balance with which the mass of the body is compared with a standard. The standard used was arbitrary at different places. The Science Museum in London has preserved an early Egyptian quartz beam mini balance as small as 80 mm length for weighing gold. The standard used was barley corns. 200 barley corns were even used as currency those days. 5760 grains of barley corn was taken as one pound. Penny weight, Avoirdupois pound, etc. were some of the earliest standards of measure of weight. For fine weighing, such as medicines, the Troy ounce – 20 grains to the scuple; 3 scruples to the Drachm and 8 drachms to the Ounce. Payments were originally made by weighing, not counting. A

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

more ancient balance called 'Trutina' (Fig.14) [4] beam double pan balance in use today and also since the time of Greeks. Around 390 BC, the Romans using a beam balance (Fig.16) for weighing war booty.



Fig. 14 'Trutina' the more ancient Single Pan Single Beam Balance [4]



Fig.15 Conventional Single Beam Double Pan Balance



Fig. 16 The Roman soldiers using a beam balance

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

VI. UNITS AND STANDARDS

6. Any measurement is incomplete if it is not expressed in proper units with standards. The International Bureau of Weights and Measures located at Sevres, France (Fig. 1) and established in the year 1875 is the fountainhead for all matters related with units.

6.1 Types of Units:

There are two types of units: i) Fundamental Units and ii) Derived Units. Let me make some historical survey before coming to this.

6.2 Systems of Units:

An "Absolute" System of unit is one in which each quantity may be expressed in terms of three (as it existed earlier) fundamental quantities length, mass and time. There are four systems of units.

6.2.1 British FPS (Foot, Pound Second) System:

The need for reproducible standards for everyday measurements led in 1861 to the appointment of a committee by the British Association for the Advancement of Science and various specifications were issued starting one with the 'ohm' which is defined in terms of resistance of a mercury column of standard length, cross section and temperature. This is the 'BA Ohm' which was in turn largely replaced in 1884 by a closely approximation the 'legal ohm' (authorized in Great Britain by order in Council); the 'International Ohm' was adopted in 1908 at the International Conference on Electrical Units and Standards. The International Ampere is that which liberates 0.001118 gram per second of silver from silver nitrate in a suitable voltameter. The International Volt is the electromotive force (emf) of Weston cell which is 1.0183 volt. This system remains historical and is not in use for science and technology. But, it is still in use in USA for trade and commerce. Before doing away with the British System, I may define the fundamental quantities in the system out of historical interest.

The 'foot' (ft) is one-third of the Imperial Standard Yard and is defined as the distance at 62°F between two specified marks engraved on gold studs which are sunk in a bronze bar of Bailey's metal (copper, tin and zinc) reserved in the exchequer's office in London.

The pound is the mass of a piece of platinum marked: "P.S. 1844 lb" 1844 referring to the year of adoption. A decade before adoption, i.e. in 1834, the standard yard and a standard pound were destroyed when the British House and the parliament were gutted in fire.

The 'second' is the duration of Mean Solar Day divided by 86,400. This was revised in 1900 by putting 'second' as $(\frac{1}{31,556,925.9747})$ of the tropical year at 12^h ET 0 January 1900. ET standing for Ephemeris Time. This was ratified in 1956 by International Conference on Weights and Measures.

6.2.2 The Metric C.G.S. (Cm, Gram, Second) System:

In the year 1790 the French National Assembly obtained Louis XVI's assent to commission the country's leading scientists to recommend a consistent system for weights and measures (It is said that Louis wrote to the king of England suggesting that French and English scientists should collaborate on this, but the Assembly did not wait for a reply and Charles Talleyrand the Chief Diplomat of Napoleon was sent to the Paris Academy of Sciences in order to help establish a new world-wide system of Weights and Measures meant to replace the then existing British System).

The report that the French scientists, Lalande, Borda, Monge and Concordet presented to the Academy of Sciences on 19 March 1791 recommended a system which was strictly followed from 1795, but took a long period to get the CGS System sanctioned in 1881. The 'cm' which is one-hundredth of the standard 'meter' kept in the International Bureau of Standards, Paris was adopted as the unit of length. (it was called 'centifranc'). The 'meter' is the length of a bar which is as nearly as possible equal to one-ten millionth $(\frac{1}{10,000,000})$ th part of a quadrant of Earth passing through Paris (Fig.17). The statement, one-ten millionth part, when made appears to be very simple. I do not think that there exists any experimental measure for this. I was dissatisfied and became more eager to know details of this and sought the help of someone who worked on the problem. Leave aside any practical experiment. One has to depend on Mathematics which is the language of Physics. This is done extensively by A Weintrit [12] from the University of Gdynia, Poland. He has published a Research Paper in an International Journal, "The International Journal on Marine Navigation and Safety of Sea Transportation, Vol.7, No.2, June 2013" and titled, "So, What is Actually the Distance

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

from the Equator to the Pole? - Over View of the Meridian Distance Approximations". Readers should necessarily go through his treatment where he has dealt with some 9 approximations by considering precisely the Earth as an ellipsoid. The final value found by the author is 10,001,965.729 meter. To maintain brevity of my paper, I have not taken any material from it but the same is mentioned in the reference for the benefit of readers. Interested readers may refer, "TransNav <http://www.transnav.eu>"

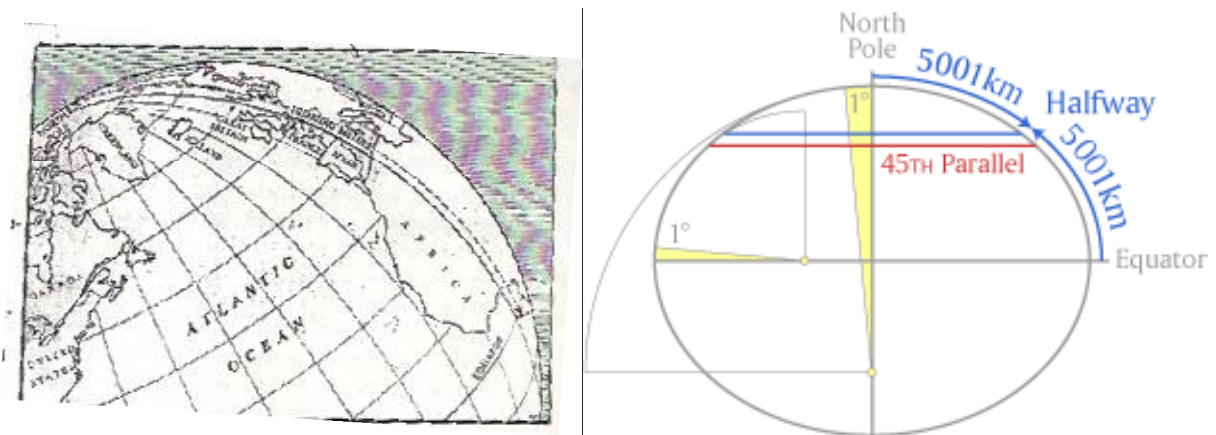


Fig.17 The distance from the North Pole to the Equator is almost exactly 10,000,000 meter

The unit of mass, the 'Gram' would be equal to the mass of a defined volume of water at its freezing point. Alternately, it is one-thousandth of the standard mass 'kilogram' which is the quantity of matter in a cylindrical alloy of platinum-iridium (80%-20%) kept preserved in the International Bureau of Standards, Paris.

The definition of 'second' which is the unit of time in this system remains the same as in the British System. A change done was that the 'Oersted' was substituted for the 'Gauss' in 1932 to represent the CGS unit of field intensity.

Legislation authorizing the construction of the new system of units, was passed on 26 March 1791 and the Metric System of measurement was born.

6.3 The Protest:

Many leading British scientists were opposed to the introduction of the metric system in Britain in 1864, which was one reason that it only became legal but not compulsory. The English mathematician and astronomer, George Airy (1801-1892) and the British mathematician, John Herschel (1792-1871) argued strongly against it, as did the Scottish mechanical engineer, William Rankine (1820-1872) who composed a poem, "The Three-Foot Rule"[10]

*Some talk of millimeters and some of kilograms,
And some of deciliters to measure beer and drams;
But I am a British Workman, too old to go to School,
So by pounds I'll eat and by quarts I'll drink and I will work by my three foot rule;
A party of astronomers went by measuring Earth,
And forty million meters they took to be its girth;
Five hundred million inches, though, go through from Pole to Pole,
So, let us stick to inches, feet and yards, and the good old three foot rule*

As quantities in this system are part of the quantities in the System International (SI) units (which we shall go through later), they are still followed even though not by agreement within the International Conference of Weights and Measures whose meeting was held in October 1964 in Paris. For most problem work, three significant figures suffice, and the 'computational (rounded)' values may be used. The data presented are based largely on values given in the National Bureau of Standards Technical News Bulletin, Vol.47, No.10 (October 1963).

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

6.4M K S (Meter, Kilogram, Second) System:

In 1935, the International Committee on Weights and Measures, the central authority on all questions of International Scientific Standards, legislated that:

*“the actual substitution of the absolute system of electrical units
(the MKS System) Shall take place on 1 January, 1940.”*

The change from CGS to MKS is to include and clarify electrical units. Electromagnetic quantities cannot be expressed in terms of the fundamental units of length, mass and time. The difficulty was solved in 1901 by a very successful Italian scientist and engineer, Giovanni Giorgi (1871-1950) (Fig.19) who showed that it is possible to combine the mechanical units of this Meter-Kilogram-Second System with the practical electrical units to form a single coherent four-dimensional system. Giorgi proposed to the *Associazione Elettrotecnica Italiana* (AEI) that one unit from electromagnetism should be added. He pursued an idea originally due to the Scottish mathematical physicist, James Clerk Maxwell (1831-1879) (Fig.18) Hence, in the year 1921 Giorgi’s proposal was thoroughly discussed by the several international



Fig.18 James Clerk Maxwell (1831-1879)



Fig.19. Giovanni Giorgi (1871-1950)

organizations to add an electrical quantity such as the Coulomb, the Ampere or the Ohm. The velocity of light is expressed in terms of ϵ_0 and μ_0 . That is, the velocity of light, $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$ and this forms the basis of the formation of MKS units. Accordingly, Giorgi suggested ‘Ohm’ the resistance of a specified column of mercury under specified conditions of pressure and temperature should be the material standard and shall form as the fourth fundamental unit. But, the introduction of Ohm brought a difficulty in dimensions of other quantities and hence between 1939-1946, the discussion led to the adoption of ‘Ampere’ the unit for electric current was proposed instead of Ohm and the proposal was finally approved in 1946 making the system MKSA System, A standing for ‘Ampere’. Giorgi died in 1950 and in the year 1954, two additional units, the ‘Kelvin’ and ‘Candela’ for thermodynamic temperature and luminous intensity respectively were added. This system is sometimes called as the Giorgi System and is a precursor for the International System (SI) of Units.

As a derivative of the MKSA System, there is the MK(force)S system is a derived unit and is called the ‘metric slug’, the ‘mug’, the ‘par’ or the TME (Technische Mass Einheit). It is defined as the mass of a particle whose acceleration is $1 \frac{m}{s^2}$ when the force on it is 1 kg force. That is,

$$1 \text{ T M E} = 9.8 \text{ kg}$$

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

VII. SI (SYSTEM INTERNATIONAL) UNITS

7.The SI Units were adopted by the General Conference on Weights and Measures the French equivalent of which is CONFERENCE GENERALE DES POIDS ET MEASURES (CGPM) in the year 1960.

7.1Basic Units:

7.1.1Length – Meter (m) - As per 11th CGPM 1960, Resolution 6

What was the need for change?

The unit of length which is the ‘meter’ defined as the distance between two fixed points on the standard bar can undergo changes. Being an artifact, it can be tampered with.Hence, according to Resolution 6 of 11th CGPM, 1,650,763.73 wavelengths of light from a specified transition in Krypton-86 atom. This measurement has an absolute uncertainty of 0.01 - .005 μm and a relative uncertainty of 10^{-8} . This definition was further revised in 1983 as per the 17th CGPM and is as follows:

7.1.2 Length – Meter (m) - As per 17th CGPM 1983[15]

The velocity of light in vacuum which is an absolute constant is taken as standard. The reciprocal of the best known value $299792458 \frac{m}{s}$ is taken as the unit of length. Hence the current definition of the meter is as under:

“The meter (m) is the length of the path travelled by light in vacuum during a time interval of $(\frac{1}{299792458})$ second”

The absolute uncertainty in this type of measurement is decreased to 0.1 nm and the relative uncertainty is 10^{-10} .

7.2Mass – Kilogram (kg) – 1st and 3rd CGPM 1889 and 1901

Kilogram (Fig.20a) and (Fig.20b) is the SI Unit of mass which is equal to “the mass of the international prototype of the kilogram [the cylindrical alloy of platinum (80%) and iridium (20%) with height and diameter both equal to 3.917 cm.]”

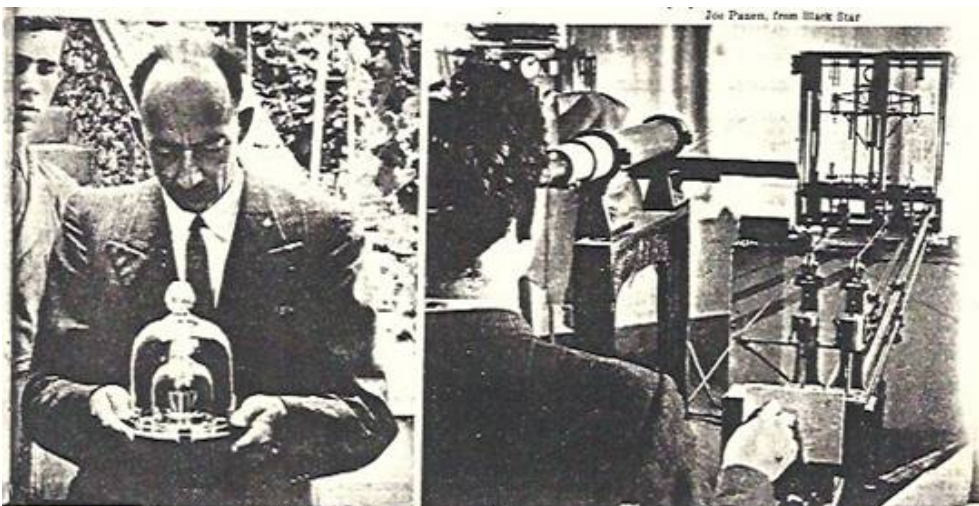


Fig.20 (a) The standard kilogram, the (b) Comparing a kilogram weight with the standard Cylinder under glass covers is kilogram at Washington (The man stands Removed from its vault every 15 feet away so that the heat from his 50 years to compare with standardsbody may not disturbthe balance.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

The definition, however, is different from the one given by the US Department of Commerce []. "The Kilogram is made of stainless steel having a volume of about 128 cm^3 in the form of a cylinder with rounded edges whose height, equal to the diameter, is about 55 mm"

The difference in the two definitions become obvious because of the fact that, when worked out, the density of the alloy of platinum and iridium with the composition as mentioned has a higher density of about $21.5 \frac{\text{gram}}{\text{cm}^3}$, whereas that of stainless steel is much lower of value $7.8 \frac{\text{gram}}{\text{cm}^3}$.

But, mass which is the quantity of matter in both remains same.

Subjectively, mass 1 kg is the weight of 1000 cc of water at the temperature of its maximum density (4°C). Initially, as per the "Treaty of the Meter" (The Meter Convention) 17 countries including the US adopted the French Kilogram as an international standard. In the year 1890, the US President Benjamin Harrison officially received the prototype 1 kg cylinder for the US. All laboratories in the world under the Treaty of Meter are advised to carry their standard kilogram to France and compare it with the one in France. Accordingly, since 1889, the US standard kilogram has been taken to France more than twice for comparison.

7.2.1. Even the Kilogram sheds weight, needs new definition:

Due to changes in weather and other atmospheric conditions, the material forming the Kilogram gets affected. (Fig.21). It is found that, over a period of time, some of the standard kilograms in various laboratories of the world have lost about 50 micrograms due to which it



Fig.21 News item, Times of India, Mumbai, 25 January, 2011.

deviates from standard. Even a fraction of the weight loss is considerable for a physicist. Moreover, the weight loss affects the definitions of other physical quantities. For example, a simple case of definition of 'Newton' which is the unit of force and defined as the force acting on a body of mass 1 kg experiences an acceleration of $1 \frac{\text{m}}{\text{s}^2}$. Thus in most of the derived units, mass appears. Getting rid of this problem appears trivial as will be seen later.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

7.3 Time – Second (s) - 13th CGPM 1967 Resolution.1

7.3.1 The need for change: The Earth while moving in its elliptical orbit around the Sun, keeps down, losing about 1 millisecond per day which adds up to 1 second (precisely 0.9 second) each Year. Thus, each new year gets delayed by one second. This creates a discrepancy between astronomical and atomic clocks. The atomic clock is the Cesium clock which is based on the transition between different energy levels of the atom. In order to match the astronomical and atomic clocks, at the beginning of each year, the atomic clocks all over the world are turned back by one second to enable the normal ones to keep up with the Earth's revolution. Cesium is used as a standard and is highly accurate, it loses just one second once in 300,000 years. Further, the hyperfine transition for cesium is in the microwave part of the electromagnetic spectrum, the technology of which is far advanced. Cesium element is plentiful on Earth and easy to handle in spectroscopy. Because of its low melting point, one can get enough vapors during operation. The definition of the International second is:

“The ‘Second’ is the duration of 9192631770 periods of the radiation corresponding to the Transition between two hyperfine levels of the ground state of the Cesium-133 atom”.

A schematic diagram of a Cesium atomic clock first developed at the Boulder Laboratories of the National Bureau of Standards, US and its principle of working is shown Fig. 22 [9]

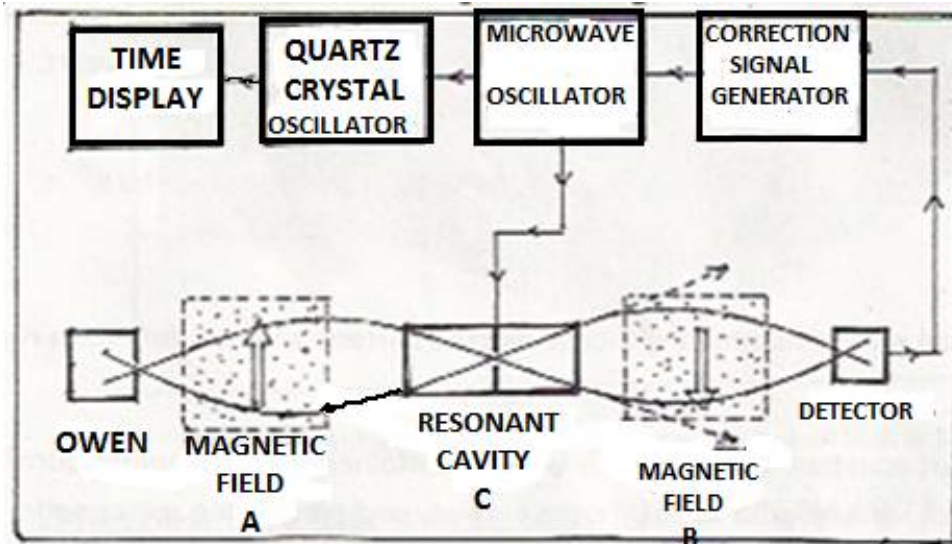


Fig.22 Schematic diagram of a Cesium Atomic Clock [9]

The cesium atom behaves like a tiny magnet. The oven in the figure serves as a source of cesium atoms which while entering are deflected by non-uniform magnetic field A. The atoms then pass through a slit S located at the center of a resonating cavity C and then enter another non-uniform magnetic field B. If no change in the effective magnetic strength of the atoms occurs while passing through the cavity, the field B just cancels out the deflection produced by the field A and the moving atoms strike the detector. If the cavity C is filled with radiation produced by a microwave oscillator and if this radiation has a sharply defined critical frequency, ν_c the cesium atoms may change their effective magnetic strength as they pass through the cavity and if this occurs, the deflection of atoms in the field B will change as shown by the dashed lines and the atomic beam will no longer strike the detector. The arrangement is such that the oscillator has a sharply defined critical frequency, ν_{cs} . This oscillator can in turn, be used to control as a control for the motion of the hands of a standard clock or to provide other convenient timing signals.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

The fundamental atomic frequency, ν_{cs} on which the cesium clock is based has been measured in terms of the standard second just defined in terms of the rotation of the Earth and is found to be $\nu_{cs} = 9192631770 \pm 20$ vibrations per second of Ephemeris Time, the particular Earth orbit being the tropical year 1957.

Modern Atomic clocks are far advanced. Cold cesium atoms forming a continuous fountain are used. The one developed in Switzerland known in 2004 as Swiss Continuous Fountain (FOCS-1), a poetic name for a machine whose function is anything but decorative is shown in Fig. 23.



Fig.23 The FOCS-1, a continuous cold caesium fountain atomic

clock in Switzerland, started operating in 2004 at an uncertainty of one second in 30 million years

The techniques employed are:

- i) Laser cooling
- ii) Narrowing the beam by high finesse Fabry-Perot cavities
- iii) Precision Laser Spectroscopy and
- iv) Counting of optical frequencies by Optical Combs

The main process, in a nut shell [3] consists of a cloud of cesium atoms being vertically launched into a vacuum. Their velocity is slowed down by laser beams. They are then measured as they drop rather than launch atoms in batches. The atoms, slowed by laser beams, are vertically launched then fall back through a hole when they are measured. The system in reality is very complex but the method is more precise than pulsed fountains having uncertainty as low as 10^{-16} .

7.4 Electric Current – Ampere (A)-Resolution 2 CGPM 1946 and approved by 9thCGPM (1948).

The definition is based on the magnetic effect of electric current. (Fig.24) The force experienced by two infinitely long, thin parallel conductors when kept one meter apart in vacuum is calculated and found to be 2×10^{-7} newton per meter of length. Thus, the definition of 'Ampere' is,

"The 'Ampere' is that constant current which when maintained in two straight

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

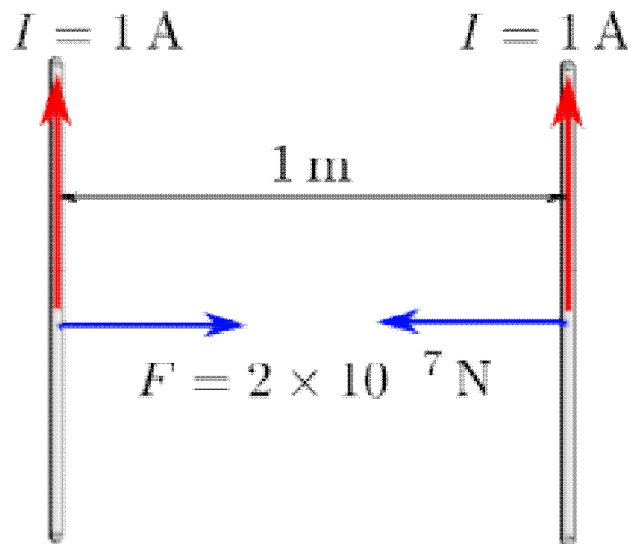


Fig.24 Illustration of the definition of the unit, 'Ampere' (Fig. Credit): [15]

“The ‘Ampere’ is that constant current which when maintained in two straight parallel conductors of infinite length, of negligible circular cross section, and placed one meter apart in vacuum, would produce between these two conductors a force equal to 2×10^{-7} newton per meter of length”

7.5 Thermodynamic Temperature – Kelvin (K) - 13th CGPM 1967, Resolution 4.

This definition is related to absolute zero which is exactly equal to -273.16°C and is the triple point of water. The definition is:

“The Kelvin of the thermodynamic scale is the fraction, $\frac{1}{273.16}$ of the temperature corresponding to the Triple Point of water”.

7.6 Luminous Intensity – Candela (cd) - 13th CGPM 1967 Resolution, 5

We would like to consider a black body or at least know what it is: A black body is any opaque surface which will absorb thermal radiation and when allowed to cool will give out all radiation received by it. The definition is,

“The ‘Candela’ is the luminous intensity in the perpendicular direction of a surface of black body of area, $\frac{1}{600,000}$ square meter at the temperature of melting platinum (2042°K) and at a pressure of 101325 newton per square meter”.

In the 16th CGPM held in 1979, the above definition is modified and re-defined as follows:

“Candela is defined as 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 $\frac{1}{683}$ watts per steradian”.

7.7 Amount of substance - mole (mol) - 14th CGPM, 1971

By a decision of the 14th General Conference on Weights and Measures held in Paris in October 1971, the fundamental unit, ‘mol’ was added to the International System of Units (SI). It is the unit for amount or quantity of substance called, ‘mol’

The amount of substance is the physical quantity determined by the number of specific structural elements (molecules, atoms, ions, etc) of which the substance consists. Since the masses of single structural elements (for example,

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

molecules) of various substances have different masses, for instance, 10^{25} molecules of hydrogen and 10^{25} molecules of oxygen are considered to be the same amount of substance though their masses differ being 33.45 gram and 531.45 gram respectively. Thus, the 14th CGPM asserted that “*Mass is not a measure of the amount of substance*”. The unit of the amount of substance is the ‘mole’ (mol) defined as follows:

“The mole is the amount of substance of a system which contains the same number of specific structural elements (molecules, atoms, ions, etc.) as there are atoms in 0,012 kg (exactly) of Carbon-12.

7.8. Supplementary Units:

There are two supplementary units:

7.8.1 Plane angle – radian (rad): Defined as “*the angle subtended at the center of a circle by an arc-length equal to the radius of the circle*”.

7.8.2. Solid angle – Steradian (sr): Defined as “*The solid angle which, having its vertex in the center of a sphere, cuts off an area of the surface equal to that of a square with sides equal to radius of the sphere*”.

Members of the Fundamental Constants Data Center (FCDC) participate in meetings of the Consultative Committee for Units (CCU) which advises the International Committee for Weights and Measures on matters concerning the SI. The latest meeting of the CCU, held at BIPM (Bureau International des Poids et Mesures in French, the English equivalent of which is, International Bureau of Weights and Measures) on June 2013 (Fig 25.) and attended by Peter Mohr, David Newell, and Barry Taylor of the FCDC.

7.8.3. Proposed Re-definition of SI Base Units: [13]

A Committee of the International Committee for Weights and Measures abbreviated to CIPM from the French, Comite International des Poids et Mesures, proposed to revise the base units and bring into effect by 16 November 2018. The main summary of the proposal is that the number of base units to remain same as 7. The kilogram, Ampere, Kelvin and mole will be redefined by choosing exact numerical values for the Planck constant, elementary electric charge, Boltzmann constant and Avogadro’s number respectively.

In the redefinition, the main trouble maker is the kilogram which is just the quantity of matter in an artifact. In the proposal for redefinition of the kilogram, the value of Planck’s constant is $h = 6.626\ 070\ 040 \times 10^{-34}$ J s the unit of which is equal to $\text{kg m}^2\text{s}^{-1}$, wherein the meter and second are defined in terms of the velocity of light c equal to $299\ 792\ 458\ \text{m s}^{-1}$ and the hyperfine splitting frequency of Cesium as $9192\ 631\ 770$ hertz.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

7.9 Derived Units: - As per 11th CGPM 1960, Resolution 12

Various physical quantities, their units in words and symbols are enlisted in the following Table-1



Fig. 25 Members of the Fundamental Constants Data Center (FCDC)

Table-1

No.	Physical Quantity	Unit in words	Unit in Symbols
1	Area	Square meter	m ²
2	Volume	Cubic meter	m ³
3	Frequency	Hertz - (per second)	Hz - ($\frac{1}{s}$)
4	Density (Mass density)	Kilogram per cubic meter	$\frac{kg}{m^3}$
5	Velocity	Meter per second	$\frac{m}{s}$
6	Angular velocity	Radian per second	$\frac{rad}{s}$
7	Acceleration	Meter per second squared	$\frac{m}{s^2}$
8	Angular acceleration	Radian per second squared	$\frac{rad}{s^2}$
9	Force	Newton (kg meter per second squared)	N - ($\frac{kg \cdot m}{s^2}$)
10	Pressure (Mechanical/Tension)	Newton per square meter	$\frac{N}{m^2}$
11	Dynamic viscosity	Newton second per square meter	$\frac{N \cdot s}{m^2}$
12	Kinematic viscosity	Square meter per second	$\frac{m^2}{s}$

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

13	Work, Energy, Quantity of heat	Joule - (Newton meter)	J - (N m)
14	Power	Watt - (Joule per second)	W - ($\frac{J}{s}$)
15	Quantity of electricity	Coulomb - (Ampere second)	C - (As)
16	Potential, Potential Difference, EMF	Volt - (Watt per Ampere)	V - ($\frac{W}{A}$)
17	Electric Field strength	Volt per meter	$\frac{V}{m}$
18	Resistance	Ohm - (Volt per Ampere)	$\Omega - (\frac{V}{A})$
19	Capacitance	Farad - (Ampere second per Volt)	F - ($\frac{As}{V}$)
20	Magnetic Flux	Weber - (Volt second)	Wb - (Vs)
21	Inductance	Henry - (Volt second per Ampere)	H - ($\frac{Vs}{A}$)
22	Magnetic flux density	Tesla (weber per square meter)	T - ($\frac{Wb}{m^2}$)
23	Magnetic field strength	Ampere per meter	$\frac{A}{m}$
24	Magnetomotive force	Ampere	A
25	Luminous flux	Lumen - (candela steradian)	lm - (cd sr)
26	Luminance	Candela per square meter	$\frac{cd}{m^2}$
27	Illumination	Lux - (lumen per meter squared)	lx - ($\frac{lm}{m^2}$)
28	Wave number	1 per meter	m^{-1}
29	Entropy	Joule per Kelvin	$\frac{J}{K}$
30	Specific heat	Joule per kg Kelvin	$\frac{J}{kg K}$
31	Thermal conductivity	Watt per meter Kelvin	$\frac{W}{m K}$
32	Radiant intensity	Watt per steradian	$\frac{W}{sr}$
33	Activity of a radioactive substance	1 per second	s^{-1}

The following are the SI prefixes: (Table-2)

Table - 2

No.	Factor	Prefix	Symbol	No.	Factor	Prefix	Symbol
1	10^1	deca	da	11	10^{-1}	deci	d
2	10^2	hecto	h	12	10^{-2}	centi	c
3	10^3	kilo	k	13	10^{-3}	milli	m
4	10^6	mega	M	14	10^{-6}	micro	μ
5	10^9	giga	G	15	10^{-9}	nano	n
6	10^{12}	tera	T	16	10^{-12}	pico	p
7	10^{15}	peta	P	17	10^{-15}	femto	f
8	10^{18}	exa	E	18	10^{-18}	atto	a
9	10^{21}	zeta	Z	19	10^{-21}	zepto	z
10	10^{24}	Yotta	Y	20	10^{-24}	yocto	y

Note: 1. The temperature interval can also be expressed in degree Celsius.

2. Old definition of litre is abrogated. According to Resolution 6 of the 12th CGPM(1964),

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

'litre' is the special name to cubic decimeter and the word 'litre' should not be used for expressing results of high precision volume measurements.

3. For practical purposes, use of units like tonne, hectare, carat, degree of angle, degree Celsius, litre, speed in terms kilometers per hour and few others is permitted
4. While writing symbols for plurals, do not add 's' to indicate plurality. For example, write 10 kg and not 10 kgs.. This is because the letter 's' is the symbol for second and may create confusion if used for plural.
5. Units with names of scientists should not be capitalized when written in full. Write newton Not Newton; watt not Watt; ampere not Ampere; joule and not Joule, etc.
6. Use the symbols as they are to avoid confusion. Write kg not kgm, kgms or kgs.

VIII. ACCURACY, PRECISION, ERROR AND UNCERTAINTY

8. The word, 'Accuracy' and 'Precision' are synonymously used. The Oxford English Dictionary defines 'Accuracy' as exactness or precision and precision as accuracy. The Fig.26 in which the bull's eye represents the true value of a measurement, will make the meaning clear.

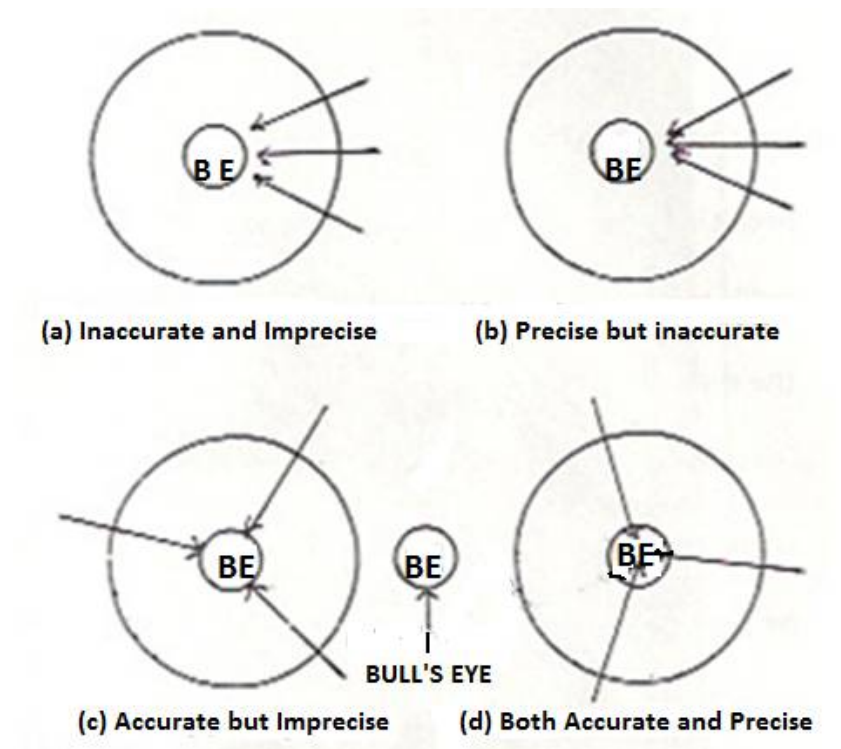


Fig.26 Illustration of Accuracy and Precision

For scientists, the distinction between accuracy and precision is important. A reading which is found to be repeatable is said to be precise. 'Error' and 'Uncertainty' must be distinguished by careful consideration. The definition given by National Physical Laboratory at Teddington, UK is, "Error is the difference between the measured value and the actual or true value of a measured quantity".

Uncertainty is the quantification of doubt about the value measured. If we say that a body weighs 200 gram plus or minus 0.1 per cent at a 95% confidence level, we can say that we are 5% true that the body weighs 199.8 and 200.2 gram. Instrumental errors can be eliminated but uncertainty can never be

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

entirely removed. It can be estimated on the basis of all possible sources of inaccuracy and then stated as a degree of confidence,

8.1.Traceability:

This is another word used by National Physical Laboratory, UK. By calibrating an instrument against a more accurate (assumed) instrument, the accuracy of measurement of the first instrument can be linked or traced back up the chain to the national standard. This demonstrable linkage to the National Standards with known accuracy is called 'Traceability Pyramid'. Fig 27. is shown a

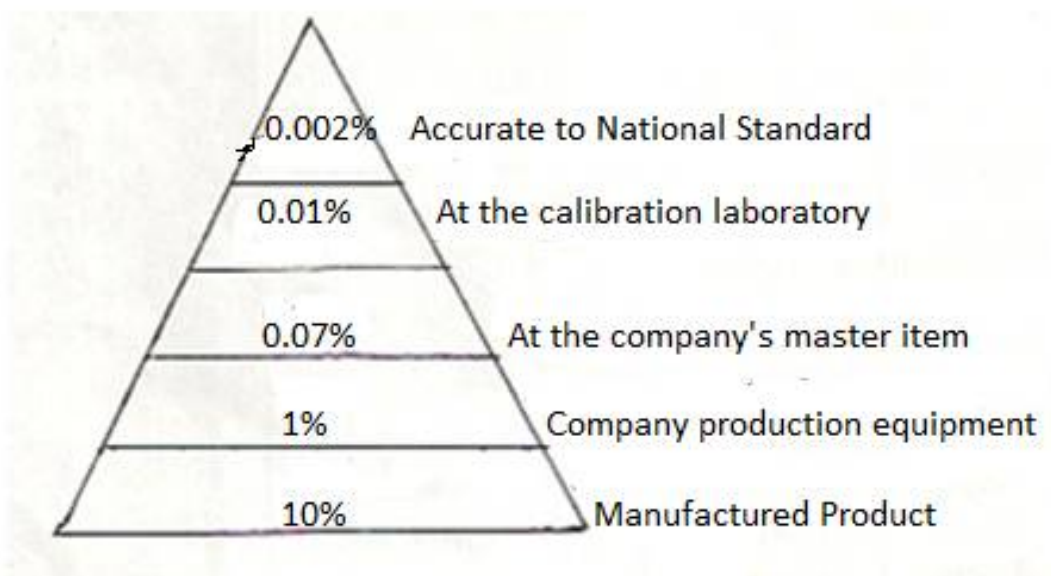


Fig. 27 The Traceability Pyramid

'Traceability Pyramid' where the uncertainty in a specification increases as we pass from a National Standards Laboratory to a manufactured product in the shops. It should be noted that Uncertainty can never be entirely removed. It can only be estimated on the basis of all possible sources of inaccuracy and then stated as a degree of confidence.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

IX. MEASUREMENTS AND DISCOVERIES: A CHRONICLE

Measurements and discoveries done by scientists from the end of the 19th century to the present in a chronological order is given in following Table-3.

Table-3

No.	Year	Measurement/Discovery	No.	Year	Measurement/Discovery
1	1880' s	Seismograph invented Electromagnetic waves measured	20	1935	Richter Earthquake magnitude introduced.
2	1884	Greenwich meridian adopted as Zero of longitude; Greenwich Mean Time (GMT) and time zones established.	21	1940's	Electronic Computers invented.
3	1888	International Phonetic Alphabet invented	22	1950's	Cesium beam Atomic Clock invented.
4	1890 s	Finger printing introduced	23	1953	Double-helix structure of DNA discovered
5	1895	X-rays discovered	24	1957	Sputnik, Artificial Satellite launched.
6	1897	Dow-Jones industrial Average invented	25	1958	Atmospheric carbon dioxide monitored.
7	1900	Quantum Theory	26	1958-60	Laser invented
8	1900-2	Blood types discovered	27	1960	System International (SI) Units introduced
9	1905	Theory of Special Relativity	28	1960's, 1970's	Theory of Standard Model explains sub-atomic particles
10	1911	Nuclear structure measured	29	1965	Cosmic Background Microwave Radiation (CBMR) detected
11	1912	IQ measured by Stanford- Binet test; Atoms measured by X-ray crystallography	30	1968-1972	Apollo Moonshots
12	1913	'Solar System' theory of Atomic Structure; Theory of Radioactive Isotopes	31	1969	International Standard Book Number (ISBN) introduced
13	1916	Theory of General Relativity	32	1970's	Electronic Calculators invented; Global Positioning System (GPS) invented.
14	1923	Decibel scale introduced	33	1975	Fractal Theory
15	1927	Heisenberg's Uncertainty Principle	34	1980's	Magnetic Resonance Imaging(MRI) invented
16	1928	Geiger-Muller counter invented.	35	1990	Hubble space telescope launched
17	1929	Expansion of Universe measured.	36	1991	World Wide Web (www) invented.
18	1931	Transmission Electron Microscope invented.	37	2004	Human genome sequenced
19	1932	Neutron discovered	38	2008	Large Hadron Collider (LHC) Particle Accelerator launched

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

X. CONCLUSION

10.1After the end of the beginning let me now really begin the end .as quoted by Charles Talleyrand. The paper has become more exhaustive and I made it more a treatise than just a treatment. Some of the related subject matter has to be presented for the readers. I re-call those words, 'Then' and 'Now' from the title of my paper so as to further emphasize the type of measurements carried out in the past and present. As a picture speaks thousand words, I have included many in the paper. In order to appease you, below are given three figures (Fig. 28 , Fig.29 and Fig.30) to be seen very carefully.

10.2.In Fig.28, a scientist, appears to be a zoologist, is seen using a measuring tape to carry out measurements on the skeleton of a large bird. Such measurements are crude measurements of ancient times. For the reading, which is the record of observation, just look at the face of the scientist having a keen observation on the object and a paper just below on his left to enter readings. In the present day tailors in the drapery trade carry out such measurements.

“Measurements” - Then and Now

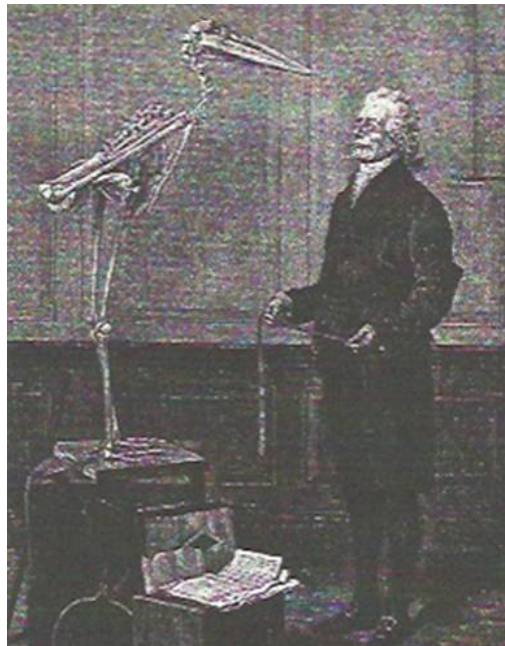


Fig.28 Measurements much earlier in the past (“Science is measurement” – An engraving from 1879-80 in which a scientist holding a measuring tape to examine the skeleton of a large bird

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

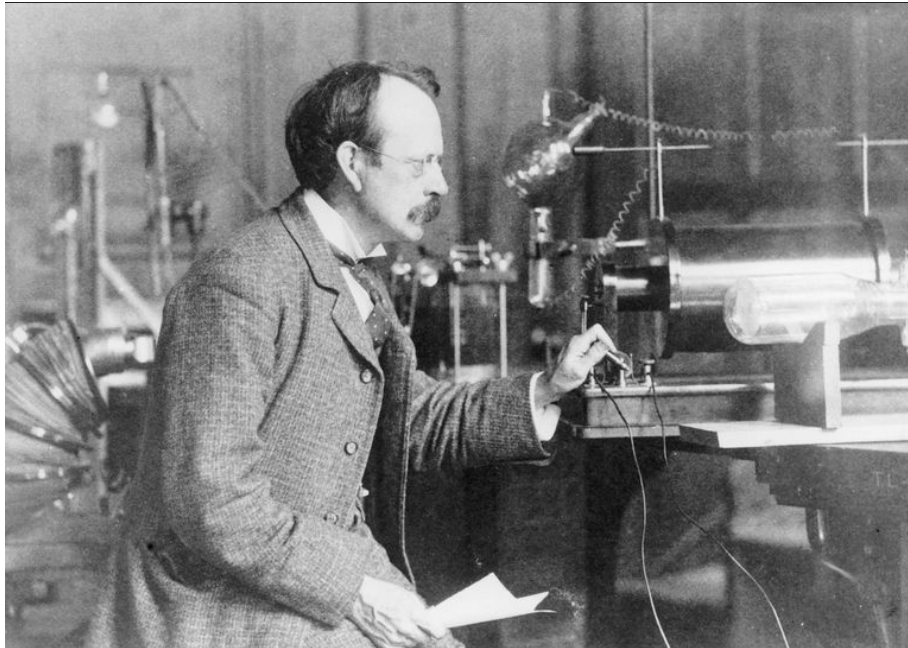


Fig.29 Measurement of the 20th century. [Nobel laureate Sir J.J. Thomson (1856-1940) very seriously performing an experiment]

10.3.In Fig.29 is shown the 19-20th century physicist, Sir J.J. Thomson (1856-1940), the discoverer and identifier of the electron and Nobel laureate (1906) very carefully and seriously performing an experiment with religious attention. In fact, modern Physics started with the discovery of electron in 1897 and the ‘Quantum’ by Max Planck in December 1900 (The dawn of the 20th century Physics started with the Quantum). In any measurement, there are three things: a) the equipment which can be a small apparatus or a handy instrument or even much larger such as the Large Hadron Collider at Geneva, Switzerland. b) The observer or the experimenter who is equally important as the equipment. Well !, readers, look at J.J. Thomson. His observation is really with religious attention and the third one is c) The readings which are the record of observation in a paper he is holding in a paper in his right hand and keenly waiting for the next observation to take the readings.



Fig.30 The greatest and wonder measurement of today [The world’s biggest Physics machine, Large Hadron Collider at Geneva (Left) and the collision of protons to produce Higgs Boson (Right)]Picture credit: Wikipedia [16]

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

10.4In Fig.30 is shown the world's biggest Physics Machine, the most powerful Particle Accelerator the Large Hadron Collider (LHC) near Geneva, Switzerland. It consists of a 27 km ring and as deep as 175 meter fitted with super conducting magnets with a number of accelerating structures to boost the energy of particles along the way. It took 16 years to build at a cost of \$ 10 billion. About 10, 000 scientists from nearly 100 countries work on this giant machine. On the right of the figure is the simulated LHC depicting a Higgs Boson produced by colliding protons decaying into hadron jets and electrons.

The high energy particle beams travelling in opposite directions close to the speed of light and collide in ultra- high vacuum in the presence of super conducting magnets maintained at -271.3°C , a temperature colder than outer space and maintained by a distribution system of liquid helium.

Well!, there is no measurement greater than that carried out here where energy unseen since a fraction of a second after the Big Bang.

Hence, at the conclusion, I shall end by saying that whether it is 'Then' or 'Now' or Aristotle to Einstein or Plato to Peter Higgs, 'Measurements' form the back bone of the development of Physics.

10.5.Measurement – The Real World Implications: [17]

In fact, I would say that "*Measurement rules the Universe*". Whether it is the prediction of an earthquake or a tsunami or prediction of an eclipse or a simple thing as prediction of weather, requires measurements to be carried out by experts and we simply read the results. I am giving below some of the real world implications due to faulty measurements or wrong reporting of results of measurements.

- a) The failure of the NASA MARS climate orbiter which was accidently destroyed on a mission to Mars in September 1999 instead of entering the orbit due to miscommunications about the value of forces; different computer programs used different units of measurement (newton versus pound force). Considerable amounts of effort, time and money were wasted.
- b) On 15 April 1999 Korean Air Cargo flight 6316 from Shanghai to Seoul was lost due to the crew confusing tower instructions (in meters) and altimeter readings (in feet). 3 crew and 5 people on the ground were killed and 37 were injured. In 1983, a Boeing 767 (which came to be known as the Gimli Glider) ran out of fuel in mid-flight because of two mistakes in figures the fuel supply of Air Canada's first aircraft to use to use metric measurements. This accident was the result of both confusion due to the simultaneous use of metric and imperial measures and confusion of mass and volume measures.

10.6.The three Bears of Measurement: - The Bear Dance.

Now, finally, the beginning of the end has come to an end and before I do it, I would like to introduce to the readers the "The Three Bears of Measurement" (Fig.31) a figure I collected from a local daily and modified. The central bear corresponds to 'MEASUREMENT' assisted by two bears on either side. The bear on the left is the 'OBSERVATION' bear and the bear on the right is the 'READINGS' bear. They are the main constituents or rather I call them as the ingredients of Measurements

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

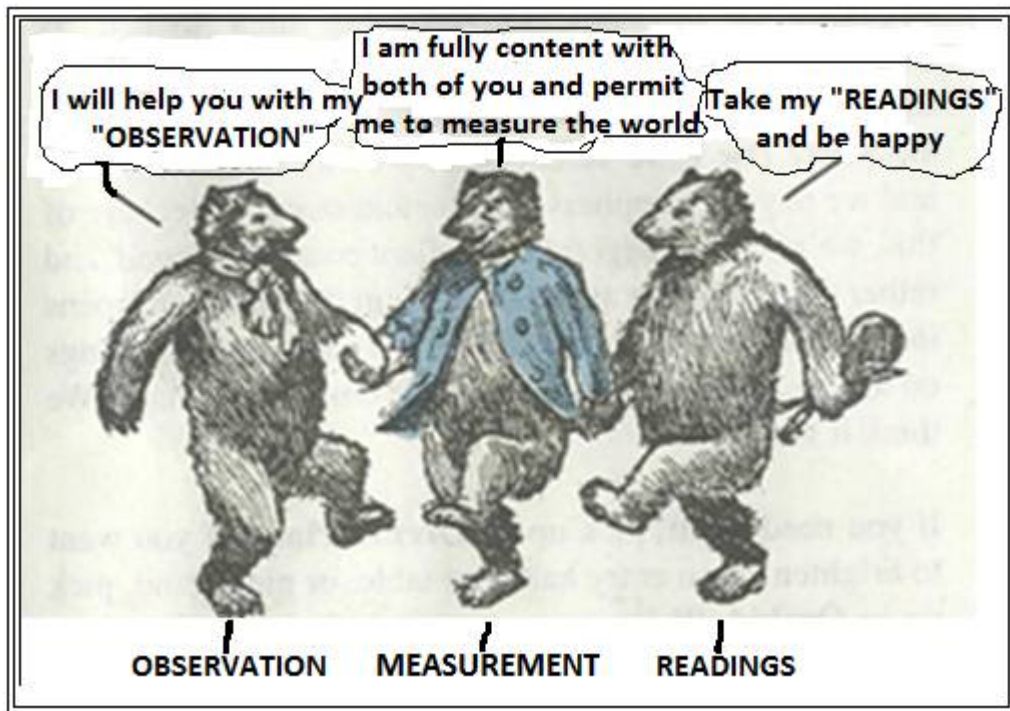


Fig.31 The Three Bears of Measurement

represented by the 'MEASUREMENT BEAR' at the center. They are all having a rhythmic dance singing as shown and the picture is highly meaningful and befitting my research paper.

REFERENCES

- [1] David Furlong, Sekeds and the Geometry of the Egyptian Pyramids
- [2] Detlef Durr – Stefan Teufel, Bohmian Mechanics: The Physics and Mathematics of the Quantum Theory, Springer Ed. 2009, Ch.5, Brownian Motion, p.109.
- [3] Fabrice Eschmann, Switzerland's atomic clock is one of a kind, HH Journal, Friday, 12 Mar.2010
- [4] James Yates, Article on A Dictionary of Greek and Roman Antiquities, John Murray, London, p.1170.
- [5] Mindy McAdams Week 2 Thursday. MMC 2265, Univ. of Florida
- [6] Nair Dr.(Prof.) V C A, Research Guide at JTT Univ. Rajasthan-333001, India "An Arm-Chair Philosophy from a Physicist", International Journal of Engineering Research and Development, Vol.12, Issue.8 (Aug. 2016), p.44-45.
- [7] National Bureau of Standards Special Publication 420. Issued by U S Department of Commerce, May 1975, p.50 Footnote.
- [8] Omelyanovsky. M.E., Dialectics in Modern Physics, Progress Pub.,Moscow, 1979, Ch.2, p.259.
- [9] Resnick and Halliday, 2nd Ed.1969 Wiley Eastern Physics Part-I, Measurement, Chapter-1, p.9
- [10] Robertson E.F, Prof. of Pure Mathematics at the Univ. of St. Andrews and O'Connor JJ.
- [11] Taylor Lloyd W, Physics the pioneer science, Vol.2, New Dover Ed. 1959, Sec.39 Magnetism, p.584
- [12] Weintrit. A, Maritime Univ, Gdynia, Poland, So, What is Actually the Distance from the Equator to the Pole? Overview of the Meridian Distance Approximations, The International Journal on Marine Navigation and Safety of Sea Transportation, Vol.7, No.2, June-2013.
- [13] Wikipedia, Proposed Re-definition of SI Base Units. Edited on 14 Aug.2017.
- [14] Wikipedia, Def. of Ampere, edited on 10 Aug.2017
- [15] Wikipedia, Def. of meter, edited on 10 Aug. 2017
- [16] Wikipedia, Large Hadron Collider (LHC), edited on 12 Aug. 2017.
- [17] Wikipedia, Real World Implications, edited on 27 June 2017

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

BIOGRAPHY



*Dr.(Prof.) V.C.A. Nair (b.15th Aug. 1939) is an Educational Physicist, Counselor, Research Guide and Consultant. He did his Masters in Physics from Mumbai University, India and Ph.D. from JJT University, Rajasthan also in India. He is a Research Guide and distinguished alumni of JJT University. He is also a Chancellor designated Resource Person in the area of Physics in the University. He has to his credit over 4 decades of teaching Applied Physics in eminent Polytechnics in Mumbai and having taught nearly 16,000 students since 1965. He has published a number of research papers in Physics and Geophysics in International and UGC recognized journals some of which can be seen in the net 'Google Search' when the name of the author is typed in that style. He is a Life Member of Indian Society for Technical Education which is an all India body. He had been to USA a number of times and visited eminent Universities such as Stanford, Harvard, MIT, University of California both at Berkeley and Los Angeles and University of San Francisco. At present Dr. Nair is a Research Guide at JJT University, Rajasthan-333001, India . His Ph.D. Thesis is in Geophysics and he is working on topics such as Tides, Clouds, Global Warming and Climate Change. – *Editor.*
[*nairvca39@gmail.com](mailto:nairvca39@gmail.com)