The Perpetuation of Ignorance
From the Metric System to System International Units

Frank H. Makinson

Abstract: The metric system of measure was formalized in the midst of the French revolution(1). The meter as a length was officially adopted on 23 June 1799 by the National Assembly of France. Those that created the metric system were unaware that the "size" of the meter would be used to establish a numeric value for the velocity of electromagnetic waves. Even after it was known that the velocity of light and that of electromagnetic waves were the same, the various "responsible bodies" did not take action to modify the value of the meter to provide a mathematically meaningful value for electromagnetic velocity. Even in 1960, when the Systeme International d'Unites (International System of Units), with the abbreviation SI, was established, it was well known that the velocity of light, represented by the symbol c, was utilized in almost all equations expressing physical law, it was allowed to retain its unwieldly value. For over a century, a variety of mathematical techniques have been developed to remove the unwieldly numeric value of the speed of light from equations, starting with Stoney units, 1881.

Missed Opportunities

In the late 1800s to the 1960s, it was apparent to anyone with a rudimentary science education that the numeric value for the speed of light (SOL) could be any value depending upon the length (or time duration) used to define it. Whether it was miles per second, feet per second or meters per second, this changing numeric value didn't have any effect on calculations as long as one used a consistent set of units. It cannot be claimed, when SI units were adopted, that a slight change in the numeric value for the SOL would cause difficulty in calculations.

In 1983, the CGPM replaced the 1889 definition for the meter, defining it as the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second. This in effect fixed the speed of light in vacuum at exactly 299 792 458 $m \cdot s^{-1}$, which provided a fixed value for the SOL that can be used as a measurement reference. The actual numeric value of the SOL was obtained by measurement, and its precision was limited by the technology available at the time of the measurement. The definition for the duration of the second had an impact on the precision and that unit will be discussed in a later section.

The "responsible bodies" that had an opportunity, at this juncture in scientific history, to select a numeric value for the SOL that was mathematically meaningful, didn't. There are a lot of numeric values that are mathematically meaningful, a good number meaningful just to physical law, and a few meaningful to both. There was no need to make a radical change in 1983.

Equation Friendly Numeric

It is apparent that a slight modification of the length of the meter would result in a equation friendly numeric value. By shortening the length of the meter slightly, the SOL could be made to have the numeric value of 314 159 265 $m \cdot s^{-1}$, or $\pi(10^8)$. This would provide a reference value with near unlimited precision.

There is another aspect of the SOL value that is never considered. Electromagnetic emissions are denoted in terms of frequency, the number of wavelengths that fit within a unit of time. When an electromagnetic emission has a wavelength with the exact length of a SI meter, the frequency will be exactly

(1) http://lamar.colostate.edu/~hillger/origin.html
(2) http://www.iupap.org/commissions/interunion/iu1/u1-2005.pdf

299792458 Hz. This coincidence of SOL velocity and frequency always existed, but it is never mentioned. One of the reasons for this omission may be that the particular frequency has no significance to any physical law other than the SOL, another being that individuals are conditioned to think of it in terms of physical motion rather than its related “electromagnetic property”.

The shortened meter would result in a SOL related frequency of 314 159 265 Hz. The $\pi(10^8)$ frequency has mathematical significance but there are no fundamental electromagnetic emissions in nature with that frequency. The section “Electromagnetic Unit of Measure” discusses the possibility of having a SOL velocity/frequency value that would be related to a fundamental emission.

Significance to SI

It is apparent that if the meter were shortened, to give the SOL a value of 314 159 265 $m \cdot s^{-1}$, all of the SI derived units that used either the SOL value or that length would be related to a fundamental mathematical constant.

Although an improvement, the numeric value of $\pi(10^8)$ in $m \cdot s^{-1}$ or Hz, will not solve all the deficiencies in SI base units. The Consultative Committee on Units (CCU) stated in its 2005 report[(2)] “the consensus that now exists on the desirability of finding ways of defining all the base units of the SI in terms of fundamental physical constants so that they are universal, permanent and invariant in time.” They did not include the meter or the second in this recommendation. The CCU did not state the desirability that the numeric value of a definition, if not 1, should be equation friendly.

In 1967 the duration of the second was redefined to correspond to the time interval equal to 9 192 631 770 periods of the transition between the two hyperfine levels of the ground state of cesium-133 atom. The reason for the change was to provide a stable reference value for the duration of the second, which had been based upon the average of the Ephemeris second[(3)]. The actual transition value, 9.192,631,770 GHz, is not used in equations dealing with physical law, the value 1 is substituted. The energy level associated with the cesium-133 transition is not really fundamental, and the transition count is valid only in rather stringent conditions. Cesium is a long way down the chain of atomic pedigree. Had the “responsible bodies” considered the value of $\pi(10^8)$ for the SOL, it would have been logical to equate the duration of the second to the same number of counts. Although this would be an arbitrary assignment, at least it would be more mathematically aesthetic than the cesium count.

When considering the above, if the main arguments against change are commercial considerations, the scientific community should establish their own units best suited for identifying physical law.

Electromagnetic Unit of Measure

It has been known since the early 1900s that frequency and energy are related, and since the 1940s that specific energy transitions within atoms are associated with specific frequencies. SI does not exploit this knowledge. Although the National Institute of Science and Technology (NIST), and equivalent groups in other countries, have what are called "Electromagnetic Metrology" divisions, these are strictly for measurement purposes and not for advocating an "electromagnetic unit of length" as a base unit of measure. The duration of the second and the candela use a frequency as a reference but not for an energy level. Had they considered using the wavelength of a specific energy emission as the basis for a length, an “electromagnetic unit of length”, SI would have become more aligned as an electromagnetic based measurement system rather than a strictly non-electromagnetic physical properties system. It is indisputable that many, and some suggest all, of the functions within the universe are electromagnetic in nature. As noted in a

(3) http://www.leapsecond.com/history/1958-PhysRev-v1-n3-Markowitz-Hall-Essen-Parry.pdf

previous paragraph, light is always expressed as a physical motion even though it is an electromagnetic process. There are an infinite number of wavelengths that represent light and other electromagnetic emissions, but we know of a finite number of wavelengths that have major significance relative to the characteristics of the universe. If the numeric value for the SOL were related to a wavelength that was associated with a fundamental physical constant, it would create a base unit set, time, energy and length, that are related to a single numeric value.

If the above were achieveable, this would simplify the current set of base units, having a core set linked as in Figure 1. The common element depicted by "######" would be that numeric value that identifies the SOL and its associated frequency, the frequency matching a fundamental physical constant. It would be desirable that the numeric value represented by "######" be reducible to an equation friendly form.

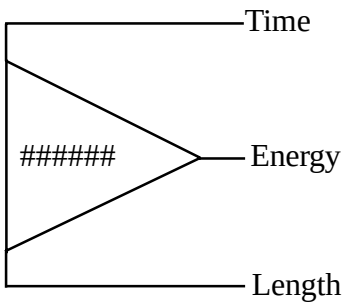

Figure 1 Time, Energy, Length

It is possible to manipulate just one or both length and the time duration to give a SOL result that would represent the frequency of a fundamental physical constant. If just one of the values was adjusted, that single adjusted unit could become a "scientific unit". This manipulation would have no real difference between the method SI used for choosing "sizes" for the current units, some human group would be making the decision as to what would change. Regardless, the resultant will deviate from current SI units, and it might be better to have a clean break from the "physical metrology" of SI units, which are derived from metric values designed more for commercial and everyday human purposes than scientific uses; see SI historical background[(4)].

Mathematical Unit Selection

Human selection of an appropriate "electromagnetic unit of measure" and time duration can be eliminated if these are determined mutually by a mathematical process. The known inverse proportional relationship between electromagnetic wavelength and frequency can be exploited to mathematically define the unit sizes and produce a numeric result for the SOL that is based upon a fundamental physical constant. The resulting values for the base units of length and time, and the numeric value for the SOL will be universal, permanent and invariant, as well as equation friendly.[(5)]

The mathematical process can be used to establish a pure electromagnetic based system of units. In 1873 James Clerk Maxwell suggested that an "electromagnetic wavelength" should be the basis for a unit of length. "The most universal standard of length which we could assume would be the wavelength of a particular kind of light... Such a standard would be independent of any changes in the dimensions of the earth, and should be adopted by those who expect their writings to be more permanent than that body."

It has been 134 years since Maxwell made his suggestion, and the current generation of scientists are being taught to perpetuate the ignorance of the creators of the meter.

(4) http://physics.nist.gov/cuu/Units/background.html

(5) http://vip.ocsnet.net/~ancient/Speed_of_Light_Derivation.pdf (######) = $\sqrt{2}*2\pi*10^8$