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Time, Energy and Space

The Mathematical Convergence of Their Units of Measure

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Abstract: The terms time, energy and space represent definitions for fundamental characteristics of the physical universe, however, the current sizes assigned to their units of measure are arbitrary and do not exploit their common link. To be valid for scientific inquiry, the base units of measure should be non-arbitrary and mutually defined based upon fundamental physical law. A simple geometric based mathematical process can be used to extract a set of base units for time and space that are mutually defined based upon physical law, and which will simultaneously identify the basis for a unit of energy. A numeric value is identified that provides the mathematical convergence of the units which describe time, energy and space.

Consensus

The 2005 final report of the Consultative Committee on Units (CCU) contained the following statement, “the consensus that now exists on the desirability of finding ways of defining all of the base units of the SI in terms of fundamental physical constants so that they are universal, permanent and invariant in time;”[1]

The base units of measure defined by the System International (SI) are the second, meter, kilogram, ampere, kelvin, mole and candela. The SI does not identify a term for a base unit of measure for energy. There are several basic problems that must be addressed to achieve the CCU’s consensus. The first issue is the tendency to define a base unit of measure in terms of human perception rather than basing it on a fundamental physical constant. A base unit defined in terms of a fundamental physical constant may not be suitable for commercial and everyday use, but this can be corrected by providing a derived definition.

Fundamental physical constants are, in the strictest sense, physical constants that are independent of systems of units. However, what the SI is actually accomplishing is defining a dimension and applying a given size to something that has been defined as a fundamental characteristic of the physical universe such that it can be used as the basis for a base unit of measure.

Natural Link

Ideally, all the base units of measure should have a natural link to some common element. This would be difficult to do for a base unit that will be associated with some physical condition related to the earth, such as mass, but it can be achieved for time, energy and space (length or distance). Figure 1 illustrates the ideally linked base units for time, energy and length. The meter and the second could have been easily defined to have a common link, but those that created the meter some 200 years ago

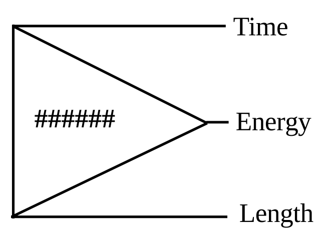

Figure 1 - Time, Energy, Length

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were unaware of the existence of electromagnetic waves, nor did they know that light was an electromagnetic phenomena, or that frequency and energy were associated. We know enough today to identify the common link between time, energy and length.

Definitions

The current definitions for time and length have a common element, but the way they are presented masks this commonality. Time, energy and length have frequency equivalent definitions. The official definitions of the second and meter illustrate their frequency equivalents.

"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." This transition count represents 9192.631770 MHz.

"The meter is the length of the path traveled by light in vacuum during a time interval of 1/299 792 458 of a second." A wavelength of one meter in length represents a frequency of 299.792458 MHz.

Energy is dimensioned using the joule and it is not a SI base unit. The joule is a relatively large amount of energy and its frequency equivalent would be extremely large. An eV was created to express energy at the atomic level and it is equated to a length of 1,239.8424121 nm (nanometers), which represents a frequency of 241,798.8407835012 GHz. That value is quite large even when related to the frequency equivalency of the second.

The time and energy frequency representations do not have values that can be identified as a fundamental physical constant. The length frequency representation is associated with a fundamental physical constant, the velocity of light, but its current value is arbitrary. As illustrated by Figure 1, a frequency that is mutually derived to represent time, energy and length would provide the basis for a scientific set of base units.

Intrinsic Units

This document is concerned with the mathematical processes that will involve a numeric value for the velocity of the speed of light, thus the material will be referring to electromagnetic wavelengths and frequencies.

Classical physics defines a wavelength as the distance between successive crests of a wave and it has a generic length with a value of 1 without an associated unit of measure. This same length can represent the circumference of a circle with a value of 1. In its circular form, the distances around the circle represent angular values. This combination wavelength/angular numeric value is defined as an "intrinsic wavelength".

Frequency is defined as the number of wave crests that pass through a given point in a specified period of time. Mathematically, frequency is expressed as the inverse of T, the duration of time, $f=1/T$. In the general definition, T can be any defined duration. Frequency can be expressed in angular form and it has the mathematical form $\omega=2\pi/T$. There is one unique numeric value where frequency and that of angular frequency have the same numeric value, 2π. That numeric point of coincidence is valid for any tens multiple or division of 2π. This combination frequency/angular frequency numeric value is defined as an "intrinsic frequency".

The algebraic equation that identifies the inverse proportional relationship between wavelength and frequency has three forms, equation (1), where f is frequency, λ is wavelength and c the speed of light, or the constant of proportionality.

$$f=c/\lambda \qquad \lambda=c/f \qquad c=\lambda * f \qquad (1)$$

The above algebraic equations do not provide a mechanism to accommodate numeric values that have dual meanings, linear and angular. The duality is fully exploited when intrinsic wavelengths and frequencies are expressed as the elements of a right triangle.

Wavelength Frequency Triangle Pair

There are no mathematical reasons why wavelengths and frequencies cannot be used to define the elements of a right triangle, Figure 2, but they cannot be mixed in the same triangle.

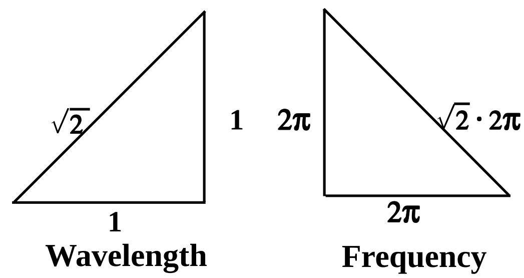

Figure 2.

When the two intrinsic values are used to define the basic elements of their respective right triangles, their geometric relationships become a function of the angle. The duality of the intrinsic values create the angular synchronization of the wavelength frequency triangle pair.

For the triangle pair the constant of proportionality is the cross product of the hypotenuse of one triangle with either leg of the other triangle. The symbol k will be used for the constant of proportionality to distinguish it from the symbol c, which is commonly used to represent a specific value using SI units. The constant of proportionality can be calculated using the symbolic dimensions of Y and Z shown in Figure 3 and the numeric values shown in Figure 2.

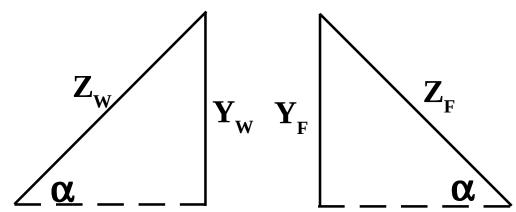

Figure 3.

When the cross products are equal it indicates that the wavelength and frequency values calculated using the triangle pair relationships are mutually related, one is the inverse of the other. The constant of proportionality is expressed by either equation (2) or (3), which are expressed in lengths, L, per "unit of time", τ (tau).

$$k = Y_W * Z_F = 1 * (\sqrt{2} * 2\pi) = \sqrt{2} * 2\pi \ \ L/\tau \quad (2)$$
$$k = Y_F * Z_W = 2\pi * \sqrt{2} \ \ L/\tau \quad (3)$$

It should be noted that the constant of proportionality can be calculated for any angle when one mutual leg of each of the triangle pair are retained as an intrinsic value. The time unit has a value of 1 when the angle is at 45 degrees, however, its actual duration and that of the actual physical length of L are indeterminate at the intrinsic level.

Practical Units

The wavelength frequency inverse proportionality does not change when the frequency is scaled. When scaled, the intrinsic frequency mathematically creates an intrinsic wavelength with a length associated with the scaled frequency. Even though the intrinsic wavelength has been scaled to a practical wavelength, its numeric value is still expressed as 1L (one length). It seems logical to conclude that scaling a fundamental mathematical value would result in a numeric value with an artificial size, however the scaling process produced a result that was unexpected.

Figure 4 illustrates the triangle pair values when the frequency has been scaled by 10^8. The leg of the frequency triangle has a numeric value of 628.31...(10^6) cpτ (cycles per unit time). The resultant numeric value for the constant of proportionality is 888.5765...(10^6) L/τ.

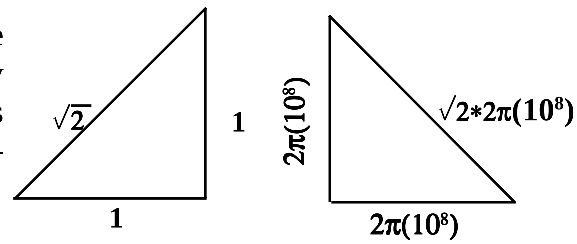

Figure 4.

The hypotenuse of the triangle represents either the wavelength or frequency of the opposite triangles legs. In the case of the wavelength and its associated frequency, the numeric value of the frequency has the same numeric value as the speed of light. Even though the frequency has been scaled by a factor of 10^8, that does not provide, to the human perception, the physical length of L or the duration of the time unit τ. These will not be determinable until the value of L and τ are related to a familiar system of measurement, i.e., SI units.

SI Units

The wavelength and frequency values of the triangle pair can be displayed in SI units, however, there is only one angle where the SI "unit of time", the second, is valid. The vertical leg was chosen to be the triangle pair element that will use their respective fixed scaled intrinsic values. The numeric value of the wavelength associated with the intrinsic frequency is known to a limited precision in SI units. The hypotenuse of the wavelength triangle represents the wavelength of the vertical leg of the frequency triangle. When the vertical leg frequency is expressed in SI units, it will give the wavelength in SI units. Using the middle formula of equation (1), and the frequency scaling factor shown in Figure 4, gives a value of 47.713... cm.

An iteration process can be used to determine the angle that will give that value for the hypotenuse of the wavelength triangle. Figure 5 denotes the numeric values of the wavelength and frequency legs, and the hypotenuses, when the angle represents the value associated with the time duration of the second. When expressed in SI units the relationships between the triangle pair are readily visualized.

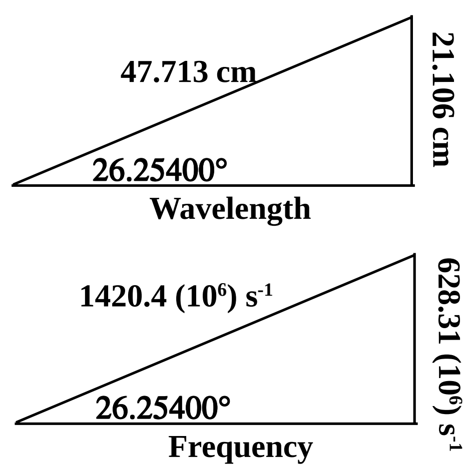

Figure 5.

The actual physical length of the scaled intrinsic wavelength was not known until it was extracted in a manner that allowed it to be compared to an existing system of measurement. The scaled intrinsic frequency is that of the precession emission of neutral hydrogen, usually referred to as the H1 hyperfine emission. In SI units, the numeric value for the practical intrinsic wavelength, its associated frequency and the angle, can be calculated only to the precision permitted by that measurement system.

The duration of the "unit of time" is a function of the angle. When the duration of the "unit of time" is assigned a value of "one" at 45 degrees, the time duration at other angles is given by the ratio of the cosecant values, equation (4).

$$R_\tau = CSC(\alpha)/CSC(45) \qquad (4)$$

The duration of the second is approximately 1.5985... longer than τ.

Conclusions

Identifying the intrinsic units and their duality was a key factor in developing the mathematical process, plus recognizing that wavelength and frequency can be presented in a geometric form. Using intrinsic units, the geometric form and known physical law, frequency and wavelength are inversely proportional, the numeric value for the speed of light was derived without knowing the physical values of the units by which it is defined.

The physical values for the units were mutually derived with the associated numeric value of $888.5765...(10^6)$ L/τ. It should not come as too much of a surprise that a unique characteristic of the hydrogen atom provides the common link between time, space and energy. The numeric value, when expressed in intrinsic units, provides a reference value for the velocity of electromagnetic waves, an energy level represented by the frequency of the H1 precession emission, and the number of counts which defines the duration of the time unit.

The use of the mathematical form for the speed of light value, $\sqrt{2}*2\pi(10^8)$, will make it convenient to use in general scientific formula, and its numeric value can be expressed to a level of precision desired for its intended purpose.

The values derived by this process will allow the creation of a set of scientific units that are universal, permanent and invariant in time, with the base units referenced to the same numeric value, Figure 6. The mathematical precision of the size of the units will be nearly unlimited, and the precision, as applied in practice, will be limited only by the technology available at any given time. The common link between the three units of measure is a frequency, which just happens to correspond to the numeric value for the velocity of light.

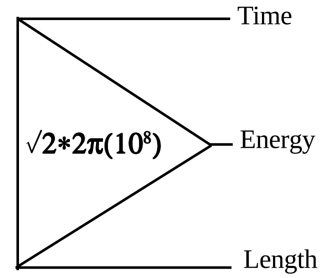

Figure 6 - Time, Energy, Length

The manner in which the mathematical correlation between time, energy and length was extracted represents a "paradigm shift" in how scientific units of measure should be defined.

References

[1] http://www.iupap.org/commissions/interunion/iu1/u1-2005.pdf