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Critical Analysis of Definitions of the Meter and the Second

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Abstract

A clarification of international definitions of the second and the meter is critical.

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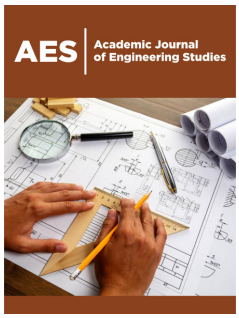

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Introduction

The exploration of minutes published by the Conférence Générale des Poids et Mesures (CGPM) between 1967 and 2019 confirms the unmissable need for accurate definitions. To define, it's to say what something is. There is no vicious circle, everything can be defined. Lack of definition and ignorance go together. A definition must be coherent, easily understandable and as concise as possible. In addition, a good definition is able to provide some theoretical extensions: the definition of the meter will provide an impressive illustration.

Definition of the Second in 1967

Let's remind two basic facts concerning the difference between a phenomenon and a concept:

A. A cycle is a phenomenon: it is observable.

B. Duration, period, second, meter, are concepts: they are not observable.

In 1967 the CGPM gave a definition of the second:

« 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 at a temperature of 0 K ».

This definition was questionable in reason of two formal defects:

A. In 1967, the word « duration » had no scientifical definition. Hence it could not be used in such an important definition.

B. The « period » is defined as the « duration of a cycle »; therefore the « duration of 9 192 631 770 durations of a cycle » is a sophism. « 9 192 631 770 periods » should have been replaced by « 9 192 631 770 cycles ».

9 192 631 770 cycles > > > 1 second

The second could simply be defined without « period » and without « duration »: The second is what corresponds to 9 192 631 770 cycles of the radiation.

Definition of the Metre in 1983

In 1983, the CGPM wrote:

« ... the value of the speed of light recommended in 1975... (c = 299 792 458 m/s) ... ». This first point is questionable because « m » and « s » were not defined yet, therefore they could not be used. In addition, the CGPM wrote: « The metre is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second »

This definition was questionable for it wears three formal defects:

A. As long as the words « length » and « time » are not scientifically defined, they should not be used in an international definition.

B. The speed of light is defined in relation to the meter and the second; and in the wake, the meter is defined in relation to the speed of light : it's a sophism.

C. The value of the meter is expressed in relation to time and to the second: accordingly it makes space to depend on time and on the second, what is wrong [1-6].

The Frequency of Caesium in 2011

In 2011, the CGPM decided: « The frequency of the hyperfine transition in the ground state of the atom of caesium 133 is exactly 9 192 631 770Hertz ». It was confirmed in 2019 [1,p. 127]. Therefore, the frequency of the caesium is a fundamental constant, as well as its wavelength [1].

The Speed of Light in 2018

In 2018 the CGPM decided: « The speed of light in vacuum c is 299 792 458m/s ». We notice that it was recommended in 1975 and already decided in 1983. This point is still questionable, because « m » and « s » are still not defined: It is a formal defect. In 2019, the BIPM use the expression « fundamental constants of nature », especially for the speed of light [1,p. 122sq]: we have explained why there are no existing constants in nature [1-3]. The proper expressions are: physical constant, constant of physics, fundamental constant ; unrelated to nature or Universe.

Definition of the Second in 2018

The CGPM defined the second: « (The second) is defined by taking the fixed numerical value of the caesium frequency $\Delta\nu_{Cs}$, the unperturbated ground state hyperfine transition frequency of the caesium 133 atom, to be 9 192 631 770 when expressed in the unit Hz, which is equal to s^{-1} ». We understand that « the second is defined by taking the caesium frequency to be 9 192 631 770 Hz ». The caesium frequency is a fundamental constant since 2011. Then we have drafted a definition of the second from the caesium frequency[3]:

9 192 631 770 Hertz > > > 1 second

« The second is a unit which corresponds to 9 192 631 770 Hz (...) ».

Definition of the Meter in 2018

The CGPM abrogated its definition of the meter written in 1983 and replaced it by: « (The metre) is defined by taking the fixed numerical value of the speed of light in vacuum c to be 299 792 458 when expressed in the unit's m/s, where the second is defined in terms of $\Delta\nu_{Cs}$ ». This definition is questionable because the meter is related to the speed of light, which is expressed in meter per second: c = 299 792 458m/s. Indeed, express the speed of light in « m/s », and in the wake, define « m » in relation to the speed of light is a sophism.

Definition of the Second in 2019

The CGPM confirms the definition of 2018 and adds this precision: « ... the second is equal to the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the unperturbed ground state of the Cs_{133} atom » [1,p. 130]. This wording is questionable for the same reasons that we have emphasized in the wording of 1967: . « duration » has not been defined by the BIPM. Duration of a period is a formal defect, because « period » is the duration of a cycle : « period » must be replaced by « cycle » [1].

We have drafted a definition [4]:

The second is a unit corresponding to

9 192 631 770 cycles of the cesium ...

We must keep in mind two important facts:

. The « second » is a concept; therefore, it owns no physical properties, in particular it is not observable.

. A « cycle » is a phenomenon; therefore, it owns physical properties, in particular it is observable.

Definition of the Meter in 2019

The BIPM repeats its wording of 2018: « (The meter) is defined by taking the fixed numerical value of the speed of light in vacuum c to be 299 792 458 when expressed in the unit $m.s^{-1}$, where the second is defined in terms of the caesium frequency $\Delta\nu_{Cs}$ »It leads to the reworded definition: « The metre is the length of path travelled by light in vacuum during a time interval of 1/299 792 458 of a second ». This definition is questionable for two reasons: The words « length » and « time » should be defined before using in such an international definition. More serious, the definition of the metre is related to « time » and « second »: a priori, it raises technical obstacles that must be addressed.

A New Definition of the Meter

We have the possibility of defining the meter in relation to two fundamental constants : the speed of light (c = 299 792 458 m/s) and the frequency of the caesium (9 192 631 770 cycles/s). What are light and caesium doing simultaneously ?

When the light travels 299 792 458 m, the caesium makes 9 192 631 770 cycles. It means that when the light travels 1 m, the caesium makes 30.663319 cycles. Hence a consistent definition without « length », « time » and « second » :

« The meter is what separates two position of a photon after 30.663319 cycles of caesium... »

We observe that the meter does not depend on the second : contrary to frequent assertions, space does not depend on time.

Conclusion

In physics, a definition must be free of formal defects, because it has force of law worldwide. This critical review confirms how crucial the precision and the coherence of the drafting of certain definitions stand. We have succeeded in defining the second and the meter in relation to two fundamental constants.

As an major theoretical extension, it proves that space is not alienated to time.

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