

# Bit, Cycle, Dimensionless, It

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**Abstract.** In this article I am using mathematical constants ("2", "e" and "2 $\pi$ "), physical constants ( $\alpha$  - inverse of the fine-structure constant and  $\mu$  - the proton/electron mass ratio), postulates and methods, to obtain relations among other physical constants. It is crucial to accept the important role of cyclicity in the Universe. The cyclicity and the bit lead to reality, which is presented by the relations between physical constants featuring  $2^x$ . Specifically, I am providing my original relation between the masses of proton, neutron and electron.

*“In science, always talk affirmatively.  
Never say: ‘It is not rainy’, rather, ‘it is sunny’.”  
Prof. Marian Čadež, PhD*

## 1. Introduction

The objective is to present the implementation of the concept of one unique dynamic Universe having the **bit** at its core. I have obtained the result after 35 years of practical work in monitoring the nature as a meteorologist. Anyone performing practical activities, whilst always applying the theoretical knowledge acquired in school, develops a critical approach to data and scientific statements, often to the extent of intuitively sensing a mistake, dead end or unsustainable standpoint. In doing so, it is of great importance to avoid scientific stereotypes, which have always existed and will continue to exist. On this journey, my role models were the great scientists whose work is behind the biggest milestones in the history of science. I will elaborate their significance in the following paragraphs.

The problem addressed is not limited to one field of physics or philosophy, therefore, specialized knowledge is not of much help. The only thing that is important here are the results that the approach generates and to what extent the results can be confirmed. The CODATA internationally recommended values of the fundamental physical constants (2010) [1] can be used for comparison of the results obtained in this article.

Overwhelmed by information overload, sometimes contradictory, we have to decide in advance which information we would pay attention to. I intuitively adopted **Occam's razor**, [2] to the extent that I rejected everything that is complicated and collides with common sense. Wikipedia is quite a good source for a start, offering easy and quick access to general information, while for more specific knowledge there are extensive resources in the literature.

Therefore, in order to explain the Universe this approach requires the following:

- *Information*
- *Cyclicity*
- *Dimensionless quantities*
- *The quantum nature of the Universe*

Of course, this does not mean that I am proposing a new stereotype or that these four postulates are sufficient for explaining the functioning of the Universe. The results can be obtained in different ways. We will see what will be obtained by the consistent application of the above postulates.

A good idea should be followed by a well-organized practical work. For this I applied:

- *Occam's razor*
- *Planck units* [3]
- *Feedback* [4]

and some other important methods such as:

- *Natural system of units*
- *Using tables to present all the relations at once*
- *Rejection of stereotypes*
- *Use of anomalies and paradoxes*
- *Positive thinking*
- *Consistency*

## 2. Bit

In the 1970s, I was a student of meteorology at the University of Belgrade. The math classes featured the discussions about Boolean algebra. The specialized courses emphasized the importance of the development of computer technology, and at the time of the exceptional role of meteorology in that development. Only the professor of dynamic meteorology, Marian Čadež, PhD, expressed skepticism, worried that the determinism in meteorology could be suppressed on account of mere mathematics and uncritical use of predetermined models. However, as an educated mathematician specialized in meteorology, he delivered a facultative lecture entitled "The significance of numbers  $2^n$  and the possibility of their application in the classification of climate conditions". The fact that the essence of the lecture was the binary system and the bit is of lesser importance than the fact that the professor, as always, expressively linked mathematics with atmospheric phenomena.

Therefore, after three decades of working with meteorological data, inspired by the wealth of information available online, I recalled that very lecture in my attempt to explain the functioning of the Universe. I dedicated the article to the quantum-dynamical explanation of the Universe, using the relations which contain  $2^n$ .

Searching the physical equations for the bit and the information, one is bound to realize that the **quantum theory** [5] of Max Planck is inevitable for understanding their connection with the reality. In the m-kg-sec system of units, Planck's constant is:  $h=6.626 \cdot 10^{-34} \text{ kgm}^2\text{s}^{-1}$ . This value is crucial for understanding the whole.

Note that dimensions are  $ML^2T^{-1}$ , especially that  $L^2$  is the dimension of the surface. Moreover, the surface has a crucial role in other cases as well, such as in:

Ostrogradsky-Gauss theorem: *Flux of force field through any closed surface which includes the charge is equal to the product of the algebraic sum of covered charges and  $4\pi$* , [6].

Holographic principle: *The amount of information that can be stored in a given volume is proportional to the surface with which it is limited.*

Second Kepler's law: *radius-vector of the Sun-planet in equal intervals of time passes equal areas.*

**To summarize, we should somehow relate the mass, area and time to the bit.**

Was the skepticism of professor Čadež concerning to the role of computers in the development of meteorology justified? I think that in specific cases it was, but in general, the informatics has brought enormous progress. Owing to the computers, the information produced by meteorologists has become much more available, timely and accurate. The role of knowledge concerning the climate change has become extremely important, while the development of meteorology as a science was accelerated thanks to the computers.

But the information itself is not sufficient for the understanding of the whole Universe. What else should be included? Another professor of the University of Belgrade, Milutin Milanković, provides us with the idea about another important natural phenomenon to help us achieve that goal - the cycles.

## Cycle

Milanković explains the long-term climate change on Earth through changes in the position of the Earth to the Sun, now known as the **Milankovitch Cycles**, [7]. I think that if there are cycles for relations between the Earth and the Sun, there are cycles on the level of galaxies, clusters, and why not of the Universe as a whole. Therefore, I am introducing the term **the Cycle of the Universe**, which in my interpretation refers to what is in the literature commonly referred to as the age of the Universe, generally attributed the value of about 13.7 billion years. I am also introducing the **Cycle**, defined by the relation:

$$cy=e^{2\pi}= 535.4916555248 \quad (1)$$

The Cycle of the Universe is expressed in the units of time, while the Cycle is a dimensionless quantity.


Milanković was not the only one to have used cycles. Many before and after him recognized the importance of cyclicity. I find that its appearance in mythology is of special importance, for example:



### **Ouroboros [8]**

an ancient symbol depicting a dragon biting its own tail. The symbol represents the realization of the full cycle, the cycle of life and eternity.

Cyclicity is even more distinctly expressed in:

<p><b>Taijitu</b> [9] symbolizes cyclicity, infinity, duality and dynamism. It consists of two equal halves containing dots of opposing colors and divided by a sine wave. The halves are inextricably linked and interact.</p>	
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However, let me explain how I avoided the issue of the number of dimensions and thus significantly simplified the approach to the explanation of the Universe. Just as in cycles, the role of Milutin Milanković is also important in the following paragraph on dimensions.



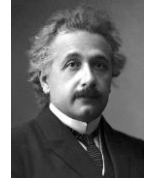
**Milutin Milanković (1879–1958)** [10]

His opinions dating back to 1926, about the dimensions in Einstein’s theory of relativity, are important here.

### 3. Dimensionless quantity

Thinking about the relations governing the Universe, not for a moment did I think of dimensions. On the Internet I found the work of Velimir Abramović, PhD, [11], related to the views of Milutin Milanković regarding the results of the **Michelson-Morley experiment**, [12] and Einstein's theory of relativity. Abramović claims that back in 1920s Milanković noticed the contradiction in presenting the movement of light, and movement in general, both in the Cartesian system and in Minkowski’s system. Milanković, as an accomplished civil engineer, practitioner, noticed the weaknesses of Einstein's "buildings".

To make it clear, I consider the works of Einstein and Max Planck the foundations of the modern understanding of physics. Errors are there so that we can learn from them. Even Einstein himself admitted some of his mistakes. He has a famous quote related to the **Cosmological constant** [13] as the "biggest blunder" of his life. Einstein’s attempts, in his old age, to create a theory of unified forces, are in my opinion worthy of admiration, despite his failure. It is a fact that many others after him tried to do the same, also without success, even though a lot of new knowledge was accumulated in the meantime.

<p><b>Albert Einstein (1879–1955)</b> [14] Einstein’s mass-energy equivalence <math>E=mc^2</math> is of the greatest importance for this article, as well as his aim to unify the laws of physics under a single model (Grand Unification Theory).</p>	
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Preparing for the FQXi contest, I was reading the works from the past and the essay of Gerry Klein from 2012, ***The Fundamental Assumption that is Wrong is the Basic Concept that a Stationary Frame of Reference can be used to Understand a Universe of Motion***, further convinced me in the correctness of my approach regarding the dimensions.

To quote professor Čadež: “If you have the impression that the sentence is wrong, try deleting it, you will see that it was not necessary.” This is one version of Occam's razor. I have

been applying this for the 35 years of my professional career, always with success. But this time it is not a sentence or a part of some act. Instead of the dimensions of space and time and the various modalities of this approach, I would single out three key qualities: mass, area and time.

This article covers the relations only of these three qualities.

#### 4. It

Relations are determined for key masses: the Universe, proton, neutron, elementary particles and some virtual masses. Similarly, relations are determined for characteristic radiuses and times. There is nothing extraordinary in the fact that the mass divided by the mass is a non-dimensional quantity. The advantage of the approach is that the rules are more easily determined in that way. For example, the role of the proton and the large number of relations related to it is quickly noticed. Since the keyword of this contest is "It", and the matter primarily comprises of neutrons, protons and electrons, dimensionless relations among them will be presented here.

Therefore, if we know the inverse of the fine-structure constant " $\alpha'$ ", proton-to-electron mass ratio " $\mu$ " and the mass ratio of Universe and proton ( $M_u/m_p$ ):

$$\alpha' = 137.035999074, \mu = 1836.15267245 \quad [1],$$

$$p = \log_2(M_u/m_p) = \log_2(1.039954 \cdot 10^{80}) = 265.8107668189$$

For simplicity, we define:  $\pi' = 2\pi = 6.2831853$  and logarithm base 2 of  $\pi'$ :  $t = \log_2 \pi' = 2.65149613$

We get the mass ratio of neutron and proton, " $\gamma$ ":

$$\gamma = 2^{(cy+p+3t)/(2+2\alpha'^2 \log_2 \mu)} = 1.00137841920390(92) \quad (2)$$

The value of " $p$ " can be represented by the relation (3), so that  $\gamma = f(\alpha', \mu)$ :

$$p = e^{\pi'} - 2 + \frac{1}{\mu/\alpha' + 2} = 265.8107668 \quad (3)$$

Why relation (3)? For now, let's say, because it gives the best results.

It is expected that the fundamental physical constants are not independent. Therefore, if the relation (2) is not valid, some other is. Even if (3) is not valid, relation (2) would then be  $\gamma = f(\alpha', \mu, p)$ . Whether it is (2) that is valid or not, determining that is of great importance.

In relation (2) and in the entire procedure, the role of bit can be noticed. Thus, for example in the relation (2) we have the logarithm for the basis 2 and  $2^x$  form of formula.

I believe that the following supports the above relations, especially the relation (2):

- The acceptable above-explained approach;
- The obtained value of  $\gamma = 1.0013784192$ , see [1];
- The correct value of many physical constants obtained by the same approach (Table 1);
- The mass ratio of the Universe and proton which is  $M_u/m_p = 2^{265.81076682} = 1.039954 \cdot 10^{80}$ ;
- The value of the Cycle of the Universe  $T_u = 4.3084906 \cdot 10^{17} \text{ sec} \approx 13.7 \cdot 10^9 \text{ years}$ ;
- The expected fractions  $1/3, 2/3, 1/2, 3/4, 3/8$  in the relations.

If only one of the above statements is not true, a relation alternative to (2) should be offered. I would emphasize that the presented approach gives the following for the Planck mass, length and time:

$$m_{pl}/M_u = l_{pl}/R_u = t_{pl}/T_u = 2^{-cy/4-p/4} * \pi^{r-3/4} = 1.2512639E - 61 \quad (4)$$

For the above-referred, see also Table 1.

We can discuss (2) if we write:  $\gamma = 2^{q^r}$ ,  $q = (cy + p + 3t)/2$ ,  $r = 1/(1 + \alpha^2 * \log_2 \mu)$ .

Then we can easily obtain that  $q$  is linked to Plank's units and  $r$  to nucleus.

A formula alternative to (2) cannot be offered, like for example (5).

$$\gamma = 1 + \ln(2\pi') / \mu - 2 / (\alpha'^3 * \pi'^2) = 1.00137841920104 \quad (5)$$

It is evident that this formula:

- satisfies the value from [1];
- is more simple than (2);
- connects the same mathematical and physical constants as (2).

Still, (5) is a speculative formula because it:

- has not been obtained by the above rational approach;
- gives less correct values of other physical constants;
- is not connected to the expected values  $1/3, 2/3, 1/2, 3/4, 3/8$  in other relations;
- is not in the form of formula  $2^x$  and neither does it have the clearly expressed role of bit and cyclicity.

## 5. Explanation by Bošković's theory of natural philosophy



**Ruđer Bošković (1711–1787) [15]**

Depending on the distance between points, attractive or repulsive force appears, which is graphically represented by Bošković's force curve. His theory is the very first quantum theory.

The explanation of my attitude could probably be found in the theory of Ruđer Bošković, [16]. He considered that the elementary particles which constitute the matter are non-extended

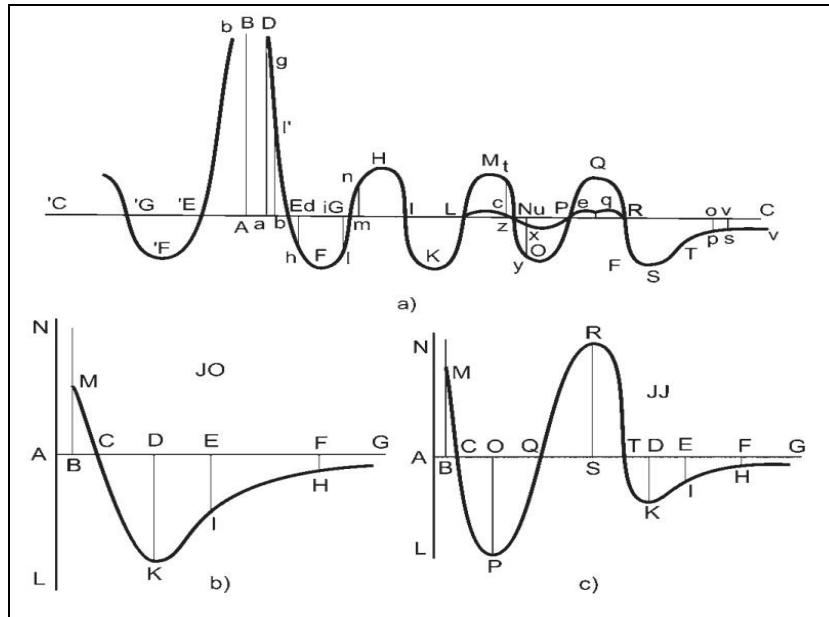
points. Depending on the distance between them, there are the determinations to be attracted or repelled (fig. 1).

Bošković emphasized the importance of distances at which the curve crosses the abscissa: R, N, I and E represent the stable, but P, L and G are the unstable positions. The elementary points are combined producing the particles of first order, which are combined producing the second order particles, etc. Thus, atoms, molecules, bodies are formed.

**It is a logical assumption that the relation is simpler between the particles of the same order, and even simpler between the neighboring points.**

**It (i.e. universality):** Bošković stated that whatever the level of the particles, the same force law (fig. 1) could explain the interactions between them. That statement has been confirmed by modern science at nine levels of matter, i.e. for the interactions between nuclear particles, electrons and nucleus, atoms, molecules up to nano-particles, macromolecules and colloids [17].

**Quants:** Bošković theory was the very first quantum theory, since the surface areas between arches and abscissa ( $\Delta E = \int F dr$ ) represent quant of energy [17].



**Figure 1.** General (a) and particular (b, c) shapes of curves that present the attractive and repulsive forces (F) (bottom and upper ordinates, respectively) vs. distance (r) (abscissa) between the elementary points and particles of matter [17].

**Bit:** Relative specific volume of matter occupied by particles at distances E, G, I... can be presented by powers of number 2 (Eq. 6), confirmed for 143 substances, as well as for the average density of solar planets [17]:

$$\begin{aligned} V_x/V_R &= 1/2^{i-1} & \text{for } x &= E, I \text{ and } N \\ V_y/V_R &= 2^{1/i}/2^{i-1} & \text{for } y &= G, L \text{ and } P \end{aligned} \quad i=1, 2, 3... \quad (6)$$

**Cycle:** During expansion or compression, particles of matter are exposed, periodically in space and time, by spontaneous attraction or spontaneous repulsion (fig. 1).

Nobel Prize laureate Leon Lederman [18] gave the highest mark to Bošković's theory, stating that it is a **key to the entire modern physics!**

**Whether there will be attraction or repulsion between two masses depends on the masses, as well as the distance.** Repulsive forces are also possible in particles with great mass (in molecules, for example).

## 6. Conclusion

Of great importance in this article is, I hope the widely-accepted view, that **parts are dependent on the whole (Universe) and are also an integral part of the whole, therefore, the whole is also dependent on the parts!**

The key novelty introduced in this article is the treatment of the life of the Universe as the cycle, and not as the age of the Universe. Therefore, the Cycle of the Universe perceived in that way has the same age at any moment as in any other previous moment. The time is related to the existence of matter (substance) and without it does not make sense. The issue of the number of dimensions is not raised, as the matter is characterized by mass, area and time. For the simplicity of approach, the natural system of units of measurement is used, in which the mass, radius and the Cycle of the Universe equal one "1". The fact that this approach gives the values of physical constants, which are consistent with the same values in [1], in all the significant digits, implies that the duration of the Universe can be treated only as the cycle. If that would not be the cycle, then the relation (2) and the relations in table 1 could give not even approximately correct result.

The second novelty is the Cycle, defined by the relation  $cy=e^{2\pi} = 535.4916555248$ , which has proved to be associated with bit, as it is in the relation (2).

The author would not go into the elaboration whether the Cycle of the Universe is the only time cycle of the Universe or not. In addition, the issues of the existence of exactly three generations of elementary particles, as well as the existence of antimatter are left aside. I believe that the above approach could help in resolving these issues as well.

Using the bit, via the cycles and dimensionless values, led to the neutrons (2), which can be considered as "it" for the topic of the contest. The relation (2) is not a coincidence. Everything preceding the relation (2) was intentionally done: bits, cycles, constants, postulates, methods, and the time the author invested.

The role of the Internet for works like this one is irreplaceable. No one can be a specialist in all the areas of physics, and all sorts of information are required to make a whole. Thanks to the bit (the Internet), we have websites, forums and blogs on the topics of science and promotion of science, which help promote the development of scientific thought.





**Max Planck (1858–1947) [19]**

Most calculations are related to the values that he has given us. Of fundamental importance for this work is Planck's constant,  $h$ .

In Table 1, the below shown values are calculated on the basis of mathematical and two physical constants (shaded). The table, in the first section, contains dimensionless constants, which of course have the same value in each system of units; therefore they are in a single column. The second segment shows the values of some important physical constants. The second and the third section have two columns, because the results are presented in two systems of units. The first can be called natural, because every mass, length and time are shown as part of a whole. In other words, mass, radius and the Cycle of the Universe are by definition equal to one "1". Planck units are in the third section. In the right are the values taken from [1], given for the sake of comparison. The values of physical quantities that are not featured in [1] can be found in other sources and are also matching the calculated values.

Each physical quantity in the table contains explicitly or implicitly  $2^x$ , although in some cases a common formula is provided that gives the same result. Notice that in the first column with data, the writing of  $\mathbf{M}_u$ ,  $\mathbf{R}_u$ ,  $\mathbf{T}_u$  can be omitted, because they, by definition, equal to one, so all the relations in that system of units can be transformed into the form:

$$\mathbf{y} = 2^x.$$

**Table 1**

<b>Input Constants or Ratios</b>	<b>dimensionless</b>			Codata
two pi $\pi^l=$	6.2831853072			(2010 value ) [1]
Cycle $cy=\exp(\pi^l)=$	535.491655525			
inverse fine structure constant $\acute{\alpha}=$	137.035999074			137.035 999 074
proton/electron mass ratio $\mu=$	1836.15267245			1836.152 672 45
base 2 logarithm $t=\log_2\pi^l=$	2.6514961295			
$b=\log_2\acute{\alpha}=$	7.0984111258			
$m=\log_2\mu=$	10.8424703056			
<b>Constants, Relations/System of measure</b>	<b>natural(<math>M_u, R_u, T_u=1</math>)</b>	<b>kg - m - sec</b>		
<b><math>p=cy/2-(\mu/\acute{\alpha}+1)/(\mu/\acute{\alpha}+2)-1</math></b>	<b>265.8107668189</b>			
Mass of universe $M_u=$	1	1.739449120E+53	kg	
Radius of universe $R_u=$	1	1.291652994E+26	m	
Cycle of universe $T_u=$	1	4.308490622E+17	sec	
Gravity coupling $c. a_G=2^{cy/2-3p/2+3t/2-2m}$	1.7516874575E-45			
Proton mass $m_p=M_u*2^{-p}$	9.6158131798E-81	1.6726217770E-27	kg	1.672 621 777 e-27
neutr. $m_n=M_u*2^{[(cy+p+3t)/(2+2\acute{\alpha}^2m)-p]}$	9.6290678013E-81	1.6749273510E-27	kg	1.674 927 351 e-27
Speed of light $c=R_u*T_u^{-1}=$	1	2.99792458E+08	m/sec	299 792 458
Classical el.radius $r_e=R_u*2^{-cy/2+p/2-3t/2+m}$	2.1816543144E-41	2.8179403267E-15	m	2.817 940 3267 e-15
electron mass $m_e=m_p/\mu=$	5.2369355359E-84	9.10938290751E-31	kg	9.109 382 91 e-31
Universal gravitat. c. $G=M_u^{-1}R_u^3T_u^{-2}$	1	6.673836011E-11	kg <sup>-1</sup> m <sup>3</sup> s <sup>-2</sup>	6.673 84 e-11
Proton Compton w. $\lambda_c=R_u*2^{-cy/2+p/2-t/2}$	1.0230378148E-41	1.3214098562E-15	m	1.321409856 2e-15
Rydberg c. $R_\infty=R_u^{-1}*2^{cy/2-p/2+t/2-2b-m-1}$	1.417425323414E+33	1.097373156854E+07	m <sup>-1</sup>	10 973 731.568 539
Planck c. $h=M_u*R_u^2*T_u^{-1}*2^{-cy/2-p/2-t/2}$	9.8373405025E-122	6.626069573E-34	kgm <sup>2</sup> s <sup>-1</sup>	6.626 069 57 e-34
Reduced P. $\hbar=M_u*R_u^2*T_u^{-1}*2^{-cy/2-p/2-3t/2}$	1.5656613679E-122	1.054571726E-34	kgm <sup>2</sup> s <sup>-1</sup>	1.054 571 726 e-34
<b>Planck units</b>	<b>natural(<math>M_u, R_u, T_u=1</math>)</b>	<b>kg - m - sec</b>		
mass $m_{pl}=M_u*2^{-cy/4-p/4-3t/4}$	1.25126390816E-61	2.17650990345E-08	kg	2.176 51 e-8
length $l_{pl}=R_u*2^{-cy/4-p/4-3t/4}$	1.25126390816E-61	1.61619877306E-35	m	1.616 199 e-35
time $t_{pl}=T_u*2^{-cy/4-p/4-3t/4}$	1.25126390816E-61	5.39105881395E-44	sec	5.391 06 e-44
area $A_{pl}=R_u^2*2^{-cy/2-p/2-3t/2}$	1.56566136785E-122	2.61209847403E-70	m <sup>2</sup>	
volume $V_{pl}=R_u^3*2^{-3cy/4-3p/4-9t/4}$	1.95905556199E-183	4.22167034884E-105	m <sup>3</sup>	
density $\rho_{pl}=M_u*R_u^{-3}*2^{cy/2+p/2+3t/2}$	6.3870771837E+121	5.15556574438E+96	kg/m <sup>3</sup>	
Energy $E_{pl}=M_u*R_u^2*T_u^{-2}*2^{-cy/4-p/4-3t/4}$	1.25126390816E-61	1.95614954730E+09	kgm <sup>2</sup> s <sup>-2</sup>	
force $F_{pl}=M_uR_uT_u^{-2}$	1.00000000000	1.21033970568E+44	kgms <sup>-2</sup>	
momentum $M_{pl}=M_uR_uT_u^{-1}*2^{-cy/4-p/4-3t/4}$	1.25126390816E-61	6.52501253818E+00	kgms <sup>-1</sup>	
power $P_{pl}=M_uR_u^2T_u^{-3}$	1.00000000000	3.62850715380E+52	kgm <sup>2</sup> s <sup>-3</sup>	
pressure $p_{pl}=M_uR_u^{-1}T_u^{-2}*2^{cy/2+p/2+3t/2}$	6.3870771837E+121	4.63359141208E+113	kgm <sup>-1</sup> s <sup>-2</sup>	

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## Appendix:

Analysis of **Hugh Matlock** at FQXi contest, August 3, 2013 @ 08:23 GMT

Using NIST website CODATA values for 2010 and previous years, I have been looking at the accuracy of your formula. I wondered, using older experimental values, how well the formula could predict the currently best known value of  $m_n/m_p$  (i.e. from CODATA 2010).

First, here is the data I used:

<i>Year</i>	<i>mass<sub>e</sub></i>	<i>mass<sub>p</sub></i>	<i>mass<sub>n</sub></i>
1969	9.1095580(540)e-31kg	1.6726140(110)e-27kg	1.6749200(110)e-27kg
1973	9.1095340(470)e-31kg	1.6726485(86)e-27kg	1.6749543(86)e-27kg
1986	9.10938970(540)e-31kg	1.67262310(100)e-27kg	1.67492860(100)e-27kg
1998	9.109381880(720)e-31kg	1.672621580(130)e-27kg	1.674927160(130)e-27kg
2002	9.10938260(160)e-31kg	1.67262171(29)e-27kg	1.67492728(29)e-27kg
2006	9.109382150(450)e-31kg	1.672621637(83)e-27kg	1.674927211(84)e-27kg
2010	9.109382910(400)e-31kg	1.672621777(74)e-27kg	1.674927351(74)e-27kg

<i>Year</i>	<i>1/alpha</i>	<i>mass<sub>p</sub>/mass<sub>e</sub></i>	<i>mass<sub>n</sub>/mass<sub>p</sub></i>
1969	137.03602(21)	1836.1090(110)	1.001379(13)
1973	137.036040(110)	1836.15152(70)	1.001379(10)
1986	137.0359895(61)	1836.152701(37)	1.0013784040(90)
1998	137.03599976(50)	1836.1526675(39)	1.00137841887(58)
2002	137.03599911(46)	1836.152667261(85)	1.00137841870(58)
2006	137.035999679(94)	1836.152667247(80)	1.00137841918(46)
2010	137.035999074(45)	1836.152667245(75)	1.00137841917(45)

In 1969 and 1973, the ratio  $mass_n/mass_p$  is not reported separately, so it is calculated from the two mass values given.

In the next table, the "CODATA gamma" is the value given in the particular year. The "Zivlak gamma" is the value obtained by using the experimental values known at the time in the Zivlak equation.

<i>Year</i>	<i>CODATA<math>\gamma</math></i>	<i>Zivlak<math>\gamma</math></i>
1969	1.001379(13)	1.0013784178(53)
1973	1.001379(10)	1.0013784162(23)
1986	1.0013784040(90)	1.00137841927(13)
1998	1.00137841887(58)	1.001378419181(10)
2002	1.00137841870(58)	1.0013784191948(93)
2006	1.00137841918(46)	1.0013784191907(19)
2010	1.00137841917(45)	1.00137841920390(92)

We now look at the success of the Zivlak equation in predicting the current value (CODATA 2010) for gamma.

The "CODATA Error" is the difference between the value given at the time (i.e. in 1969 and so on) and the current 2010 value, as a proportion of the 2010 value.

The "Zivlak error" similarly is the difference between the value that could have been calculated at the time with the current 2010 value, as a proportion of the 2010 value.

The C Error/Z Error column shows the ratio of the CODATA error to the Zivlak error.

There are several things of note.

(1) First, note that, for all years, the Zivlak gamma is significantly closer to the current known value than the value that was obtained at the time via the sophisticated methods of CODATA. For example, in 1973, it was 3758 times more accurate (this is partially due to the fact that the  $m_n/m_p$  ratio was not disclosed by CODATA).

(2) By 1986, the Zivlak equation had produced a value that is more accurate than the value we have from CODATA even today.

(3) Perhaps most surprisingly, even when we compare the 2010 CODATA value against itself as the gold standard, the Zivlak value is superior. This is because it predicts a (slightly different but very precise) value with very little uncertainty. The larger uncertainty in the 2010 CODATA value means its average error is higher.

These results suggest that the Zivlak formula for the ratio of neutron to proton mass has real predictive power. Please accept my congratulations for your work on this!

Hugh