

Proposal for the Universal Unit System

Takashi Suga, Ph.D.

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Abstract

We define the Universal Unit System based on the combination of fundamental physical constants and propose the Harmonic System as its practical implementation.²

1. The Universal Unit System

1.1. Before the Universal Unit System

A unit of measure is “a quantity that is used as the basis for expressing a given quantity and is of the same type as the quantity that is to be expressed”. A unit that is used in exchanges between people must be guaranteed to have a constant magnitude within the scope of that exchange. Quantities that can, by consensus, serve as common standards over a broad scope were sought and selected to serve as units. The ultimate example of such a quantity is an entity common to all of the humankind, the Earth itself, which was selected as the foundation for the metric system.

1.2. The next stage?

Of course, we can consider going beyond the framework of the Earth and defining units with concepts for which agreement can be reached within a broader scope. The quantities that then become available to serve as the standards for defining units include the quantities of the fundamental physical constants, quantities such as the speed of light in a vacuum (c_0), the quantum of action (\hbar), the Boltzmann constant (k_B), and so on. These quantities are believed to have values that remain constant everywhere in the universe. When trying to construct a coherent unit system, however, it is not possible to use all of the fundamental physical constants in the definitions of units. Therefore, would not we expect the fundamental physical constants that were not used in defining

¹ In this paper, SI units are combined only with the decimal figures (indicated by a period “.” as the radix point), and units of the Universal Unit Systems are combined only with duodecimal figures (indicated by a semicolon “;” as the radix point. ‘X’ expresses ten and ‘E’ expresses eleven). Both notations may use a comma “,” and “_” as the digit group separator. Non-dimensional quantities are mostly expressed using all figures in duodecimal first, with the decimal given parenthetically. There are also cases where the octal radix point is represented by “@”.

² This paper revises the paper currently retrievable at <http://dozenal.com>. See also footnote 26. The first Japanese version was released May 1194;(1984.)

units to have fractional magnitudes of unit quantities of the same dimension?

For example, the Rydberg constant (R_∞) is 115,3789;470078/ft (10973731.56816/m)³ and the Bohr radius (a_B) is 0;X8EE6E525×10;⁻⁹ft (5.29177210903×10.⁻¹¹ m). Therefore, the relation between these two constants is:

DOZENAL	DECIMAL	
$R_\infty^{-1} = \text{EE6;06603 } a_B$	$R_\infty^{-1} = 1,722.04515 a_B$	(1)

If one of these two constants is chosen as a unit quantity, the other constant cannot be expressed as a unit quantity.

By surprising coincidences⁴ described in Appendix F and §2.1 of <http://dozenal.com>, however, if the duodecimal number system is used to express the speed of light in vacuum and the quantum of action as the defining constants such that these constants are strictly multiples of integer powers of twelve of the unit quantities, it is possible to construct a coherent unit system in which not only the constant that was used in the definition but also the Rydberg constant, the Bohr radius, the unified atomic mass unit (u), and half the value of the Planck length ($l_P/2 = \sqrt{36 \cdot G\hbar/c_0^3}/12$.) can be approximated to about or within an error of 2 per gross (1^{1/2}%) by a multiple of integer powers of twelve of the unit quantities.

In that case, many other physical constants, including the charge and mass of an electron, the fine structure constant, the molar volume of an ideal gas under standard conditions, the black-body radiation at the ice point, the density and surface tension of water, and others, can be approximated by multiples of integer powers of twelve of the unit quantities. Moreover, by adding the Boltzmann constant and using it in the definition of thermodynamic temperature, the gas constant of an ideal gas can be approximated by a multiple of an integer power of twelve of the unit quantity and the Stefan-Boltzmann constant, and the specific heat of water can be approximated by multiples of integer powers of twelve of the unit quantities with a factor 2 remaining. These conclusions are shown in Table 5.⁵

For putting these coincidences to use, the duodecimal number system is the only choice.

It seems that the combination of fundamental physical constants “forces” us to use base twelve.

We define the Universal Unit System as “the unit system that is constructed by using the duodecimal number system and the speed of light in vacuum, the quantum of action, and the

³ In this paper, plane angle phase factor 2π is often treated as a non-dimensional parameter and omitted in order to simplify the explanation. See §A.2 and 3.2.2 of the paper <http://dozenal.com> .

⁴ To prevent any misunderstanding, let us emphasize that **these are merely coincidences as far as physical science is concerned.**

⁵ A more detailed table is retrievable at <http://www.asahi-net.or.jp/~dd6t-sg/univunit-e/condensed.xlsx>.

Boltzmann constant as the defining constants in such a way that these constants become strict multiples of integer powers of twelve of the unit quantities, and the Rydberg constant, the unified atomic mass unit, the Bohr radius, and half the value of the Planck length can be approximated by multiples of integer powers of twelve of the unit quantities”.

1.3. Variation of the Universal Unit Systems

To define three units for time, length, and mass, the Universal Unit System uses the speed of light in vacuum and the quantum of action. Another constant is necessary to define these three units. Therefore, the Universal Unit System has some variations in the constant that the system chooses as the last definition constant.

Universal Unit System with constant A is the Universal Unit System that uses constant A as the last definition constant and whose unit quantity of the last dimension is equal to constant A or its multiples of integer powers of twelve. In particular, the Universal Unit System with the Rydberg constant whose length unit is $10^{10} / R_{\infty}$ ($12 \cdot 10^{10} / R_{\infty}$) and velocity unit is $10^{10} c_0$ ($12 \cdot 10^{10} c_0$) is called the Universal System of Units Standard⁶ corresponding to the International System of Units Standard (SI). We will use a symbol corresponding to the SI unit symbol suffixed with ‘u’ as a new symbol required by the Universal System of Units Standard; ‘u’ is the ‘universal’ system suffix. The noun form is ‘univer’. For example, the length unit is m_u and is called the ‘universal meter’ or simply the ‘univer’⁷, and the time unit is s_u and is called the ‘universal second’⁸. **This unit system is comprised of six quartets.** The units of this system are listed in the 5th column of Table 4, and physical, material, and astronomical constants expressed using this system are presented in the 3rd column of Table 5. The ratio of the time unit s_u and the SI second is 0;4824707(0.3902675).

The Universal Unit System with the Bohr radius whose length unit is $10^{10} a_B$ ($12 \cdot 10^{10} a_B$) and velocity unit is $10^{10} c_0$ ($12 \cdot 10^{10} c_0$) can be defined in the same way. Its time unit is 1;005E857 s_u (0.3916171 s). Roughly speaking, **if a time constant or its multiples of integer powers of twelve falls within the range between 1; s_u (0.3902675 s) and 1;005E857 s_u (0.3916171 s), we can construct the Universal Unit System using the constant as a time unit.**

⁶ The Universal System of Units Standard is strictly defined in §3 of the paper <http://dozenal.com>.

⁷ The noun form of the system suffix is considered to be the abbreviation of the length unit like the length unit of the metric system is ‘meter’.

⁸ Note that there is no vagueness at all even if the suffix is omitted if the notation of footnote 1 is adopted. Suffixes are necessary to identify plural Universal Unit Systems mutually. $4 \times 10^7 m$, $4 \times 10^7 m_u$, and the Earth’s meridian length are nearly equal. $10^{10} s$, $10^{10} s_u$, and $1 \frac{1}{8}$ days are nearly equal.

If half the value of the Planck length is used instead of the Bohr radius, the time constant becomes 1;0223 s_u (0.3962 s). This is out of range. To keep the time constant within the range, we should use $\sqrt{35.Gh/c_0^3}$ instead of $\sqrt{36.Gh/c_0^3}$. Then, the time constant becomes 1;00186 s_u (0.39065 s). We call this system the Gravitic System. The Gravitic System can be interpreted as a unit system that 35. G , α , \hbar , K_B and Z_P are strict multiples of integer powers⁹ of twelve of the unit quantities. However, it is not practical because G 's measurement accuracy is insufficient.

2. The GCD Unit System

2.1. Basic Concept

The length of the tropical year is strictly 265;2XX6 days in a certain year at the end of the 20th century. For human activities on Earth, year and day cannot be ignored as calendar time units. However, the ratio of year and day is not simple. **Therefore, any calendar time unit system must be a mixed radix system.** The ratio of one tropical year and one day is:

$$\begin{array}{l} \text{DOZENAL} \\ \frac{\text{year}}{\text{day}} = 265; + \frac{27}{X8}; = 1; 003628 \times 264; 6 = 1; 003628 \times \frac{3^6}{2} \\ \text{DECIMAL} \end{array} \quad (2)$$

$$\frac{\text{year}}{\text{day}} = 365. + \frac{31.}{128.} = 1.002036.. \times 364.5 = 1.002036.. \times \frac{3^6}{2}$$

Because one year consists of twelve months, it is reasonable to adopt twelve as one of the radices. Though this ratio contains the extra factor 3 six times,¹⁰ by multiplying by factor 2⁶(= 8 × 8) twice, we can cancel factor 3 and obtain powers of twelve(= 3 × 2 × 2):

$$\begin{array}{l} \text{DOZENAL} \\ \frac{2^6 \text{year}}{2^{-6} \text{half day}} = 2^6 \times 1; 003628 \times \frac{3^6}{2} \times 2^7 = 1; 003628 \times 10;^6 \\ \text{DECIMAL} \end{array} \quad (3)$$

$$\frac{2^6 \text{year}}{2^{-6} \text{half day}} = 2^6 \times 1.002036.. \times \frac{3^6}{2} \times 2^7 = 1.002036.. \times 12.^6$$

If we define ‘octal century’ as 2⁶ years, and define ‘clock’ as 2⁻⁶ of a half day, the relation between these two units is:

⁹ If these integers are all set to 0, various constants are approximately expressed as follows: https://en.wikipedia.org/wiki/Talk:Planck_units/Archive_3#Other_possible_normalizations .

¹⁰ Yang Xiong (45;(53.) BCE–16;(18.)) used the ratio 3⁶/2 in his Tai Xuan calendar (太玄曆).

See Hideki Kawahara “Chinese Scientific Thought (中国の科学思想)” 11X4;(1996.) [ISBN: 978-4423194126] and Wikipedia [http://en.wikipedia.org/wiki/Yang_Xiong_\(author\)](http://en.wikipedia.org/wiki/Yang_Xiong_(author)).

$$\text{octal century} = 1;003628 \times 10^6 \text{ clocks} \quad (4)$$

There are some interesting coincidences. Also, please see Table 1.

- One clock is the difference between a tropical year and a Julian year.
- One clock is the greatest common divisor (GCD) of the length of a day and a tropical year.
- Two octal centuries are the least common multiple (LCM) of the length of a day and a tropical year, and so leap year rules become simpler than those of the Gregorian calendar.
- The geometric mean of one octal century and one clock is approximately one fortnight.

Table 1 Coincidences of rotation and revolution of Earth and other planets

Quantity A	Quantity B	Type	Common Quantity
day	Julian year	GCD	1/4 day
		LCM	4 years
	tropical year	GCD	$1/X8;(2^{-7})$ day
		LCM	$X8;(2^7)$ years
year	rotation of Venus	LCM	2 years and -3 rotations
	revolution of Venus		8 years and 11;(13.) revolutions
	revolution of Mars		28;(2 ⁵) years and 15;(17.) revolutions

It seems that the combination of the rotation and revolution of the Earth “forces” us to use base two in the middle of the calendar time range. People have a proclivity for using large units for large quantities and using small units for small quantities, so we can cover a wide calendar time range by a duodecimal number system using the following hierarchy shown in Figure 1 (a) ¹¹.

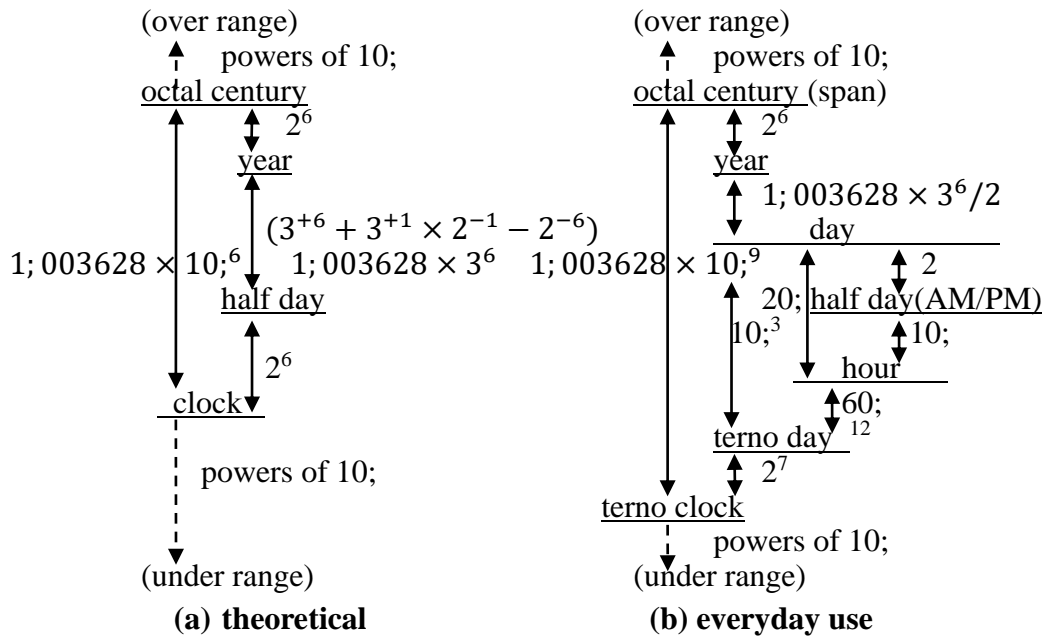


Figure 1 The GCD Unit hierarchy

¹¹ A more detailed figure is retrievable at <http://www.asahi-net.or.jp/~dd6t-sg/univunit-e/TimeScale.pdf>.

¹² See Appendix C for ‘terno’. A terno day is equal to H. C. Churchman's ‘moment’. Please see <http://www.dozenal.org/archive/DuodecimalBulletinIssue112-web.pdf>.

We define ‘the GCD Unit’ as “the GCD of the length of a day and a tropical year, or its multiples of integer powers of twelve”, and ‘the GCD Unit System’ as “the 2:10;(2:12.) mixed-radix calendar time system using a day, a tropical year, and the GCD Unit”. **It is very natural to adopt a unit of calendar time that is an integer division of both a year and a day.**

2.2. Everyday use

Calendar time units are the most conservative units. Considering the easiness of the shift from the present 10;:50;(12.:60.) mixed-radix system to the future 2:10;(2:12.) mixed-radix system, there are some variations of connection points of the binary number system and duodecimal number system¹³. A variation designed for everyday use is shown in Figure 1 (b) and Table 8.

$$1 \text{ day} = 10;^3 \text{ terno days} = 10;^3 \times 2^7 \text{ terno clocks} \quad (5)$$

This is a variation that is designed to maximize the range expressed by multiples of integer powers of twelve of a day. This permits ‘half day(AM/PM)’ and ‘hour’ to be used for clock notations. That is, the following four clock notations are all available. The notation ‘hour’ may fade out.

Table 2 Clock Notations

clock notation	format	2:10;(2:12.) system	10;:50;(12.:60.) system
10;-hour notation	H:TT’NN;nn...(AM/PM)	3:16’28;0 PM	3:15:12.5 PM
20;-hour notation	HH:TT’NN;nn...	13:16’28;0	15:15:12.5
1000;-terno day notation	UTT’NN;nn...	776’28;0	Not used
10;-unino day notation	TT(to[-]/after[+])U	46; terno days to the 8 th unino day	15 minutes after 3 PM

Following the Titius-Bode law, the orbital semi-major axis of planets can be approximated by $(3 \times 2^N + 4)$ light solar terno days (see also Table 8), where $N = -\infty, 0, 1, 2, 4, 5, 6$ (Mercury, ..., Uranus). Ratio $2^7:1$ is the same as the ratio of the U.S. liquid gallon and fl oz. **The Harmonic Ratio $2^7:10;^2$ (8:9)** corresponds to the major tone of the just intonation.

3. The Harmonic System

The GCD Unit is derived from the combination of the rotation and revolution of the Earth without using the Universal Unit System concept. However, we encounter the final surprising coincidences. 1; terno clock is equal to a day/($10;^3 \times 2^7$). It is equivalent to 1;0016EE1 s_u (0.3906250 s). Therefore the equivalent value of 1; terno clock falls within the range between 1; s_u (0.3902675 s) and 1;005E857 s_u (0.3916171 s). This value also almost agrees with the time constant of the Gravitic System 1;0018 s_u (0.3906 s). We can construct the Universal Unit System with the GCD Unit! ¹⁴ The Dozenal Society of America seems to recommend ‘dour’(day/10;) and ‘moment’(day/10;^3). Of

¹³ See detailed discussion in <https://www.tapataalk.com/groups/dozenonline/the-universal-unit-system-f34/>.

¹⁴ See the sheet ‘Clock’ in <http://www.asahi-net.or.jp/~dd6t-sg/univunit-e/condensed.xlsx>.

course, these units are all available, but because the calendar time unit system includes ‘year’ by all means, it does not become a pure duodecimal system even if we choose $1/10;^2$ of ‘moment’ as a unit.

We can enjoy all the advantages of Table 5 if we choose not $1/10;^2$ but $1/2^7$.

Because of tidal friction, the physical time length of a day is not constant and becomes longer little by little.¹⁵ A length unit can be redefined exactly as $100,1700;/R_\infty$ so that a physical time unit becomes exactly $1;001700 s_u$ (0.3906251 s) and approximately $1;0016EE1 s_u$ (0.3906250 s) similar to the redefinition of SI units to provide better stability and reproducibility. The calendar time unit length will strictly correspond to the physical time length of a day about 20; octal centuries (1400. years) later. We call this redefined system ‘the Harmonic Universal Unit System with the GCD Unit’, ‘the Harmonic Universal Unit System’, or simply ‘the Harmonic System’ and will use the suffix ‘h’ for units of this system. ‘h’ is for ‘human’ or ‘harmonic universal’ system suffix. The noun form is ‘harmon’. For example, the length unit is m_h and is called ‘harmonic universal meter’, ‘harmonic meter’, or simply ‘harmon’. We specifically granted dedicated aliases for the Harmonic System’s length, time, mass and impedance unit. Please see footnote 25 on ‘harmon’, ‘nic’, ‘looloh’ and ‘nohm’.

We notice that the Harmonic System is also a unit system that redefines the Gravitic System which is not practical because G’s measurement accuracy is insufficient. In other words, the Harmonic System can also be said to have given a strict and practical definition to the conceptual Gravitic System.

The units of this system are listed in the 7th column of Table 4 and physical, material, and astronomical constants expressed using this system are presented in the 4th column of Table 5. Please see also Table 6 and Table 7 for details. The approximations shown in Table 5 are remarkable. For putting coincidences described in this paper to use, the duodecimal number system is indispensable. **We hope that the Harmonic System is acceptable for humans on Earth.**

A. The Earth local extension

The Earth local extension, which consists of five units, and three supplementary constants, is designed for local use on Earth. Please see Table 8.

In this scheme, the CGD unit system is treated as part of the Earth local extension. **To distinguish calendar time units from physical time units, we regard the dimension of calendar time units as the plane angle.**¹⁶

¹⁵ See Stephenson, F. R.; Morrison, L. V. (April 11X3;(1995.)) “Long-term fluctuations in the Earth’s rotation: 700 BC to AD 1990.” retrievable at <http://adsabs.harvard.edu/abs/1995RSPTA.351..165S> .

¹⁶ See Seaman, Rob (April 11XB;(2003.)) “A Proposal to Upgrade UTC” retrievable at <https://web.archive.org/web/20150419125423/http://iraf.noao.edu/~seaman/leap/>. It seems that the dimension of

The newly introduced temperature unit °H (degree H) is designed to meet the relationship that 100; °H corresponds to the boiling point of water (99.9839 °C). The quantity expressed by the unit °H is the difference between thermodynamic temperature and 118,2354; K_h (approximately -74.36°C). The interval of unit °H is one **H**yper Kelvin (=1,0000; K_h≐1.210724 K).

The supplementary constant g_E is used to represent any force quantity as a corresponding mass quantity, like 1 ℓℓ g_E (one looloh gee). In the same way, the supplementary constants s_E and m_E are used to represent any physical time and length quantity as a corresponding plane angle quantity.

B. Gravitational constant and gravity field equations

The equations of some categories¹⁷ can be used efficiently if we introduce new constants. At this time, the total solid angle of a sphere¹⁸, Ω₂, and the speed of light in vacuum, c₀, appear in the equations. This is the reason that the speed of light in a vacuum should strictly be multiples of integer powers of the base number of the unit quantities.

When representing the mass of a celestial body using the Universal Unit System, the gravitational radius (half the Schwarzschild radius) is used rather than using mass directly. Because the accuracy of measuring the Newtonian constant of gravitation is poor, representing the mass of a celestial body directly in terms of mass results in poor accuracy, but the gravitational radius can be measured to an accuracy of around ten digits.

If we define a new constant that has the dimension ‘force’ as ‘the Planck force’, there is a good chance that the geometrical parts can be separated from the coefficients in the formula¹⁹. Make the Planck force, $F_P = c_0^4 G^{-1} = \hbar c_0 / l_P^2 = 35. \hbar c_0 / m_G^2$, then:

$$\text{gravitational radius, } r_m = \frac{Gm}{c_0^2} = \frac{mc_0^2}{F_P} \text{ (half the Schwarzschild radius)} \quad (6)$$

$$\text{gravitational force, } f = F_P \frac{r_m r_{m'}}{r^2} = c_0^2 \frac{r_m m'}{r^2} \quad (7)$$

$$\text{gravitational acceleration, } g = c_0^2 \frac{r_m}{r^2} = \frac{r_m}{(r/c_0)^2} \quad (8)$$

$$\text{gravity field equation, } \frac{T_{ik}}{F_P} = \frac{1}{2\Omega_2} \left(R_{ik} - \frac{1}{2} R g_{ik} + \Lambda g_{ik} \right) \quad (9)$$

the quantity of a day (=calendar time) should be a plane angle rather than physical time. The calendar time is, in a word, the rotation angle of the Earth derived by using the direction of the sun as a coordinate origin.

¹⁷ For a case of electromagnetism, see §B of the paper <http://dozenal.com>. In the electromagnetic field, the natural unit of impedance, Ω_n (=Z_P: the Planck impedance), plays the role of the Planck force in the gravitational field. Ω_n, e, θ_w, and F_P are constants for the four fundamental forces.

¹⁸ See electromagnetic units in Appendix E and §3.2.2 of the paper <http://dozenal.com>, and <http://www.asahi-net.or.jp/~dd6t-sg/univunit-e/electromagnetism.pdf>.

¹⁹ Please note that Eq. (8) and (9) are geometrical and have no mass dimension.

C. Number Counting

Many of the constants introduced in footnote 9 often have orders $8n - 1$.²⁰ Therefore, it is convenient to use the factor $U(=10;^8(12.^8))$ to make the units of the Universal Unit System into human scale. The factor U can be regarded as a conversion factor between atomic scale, human scale, and cosmic scale. Since power $8(=2^3)$ is a power of 2, the decimal myriad system²¹ has affinity for our system. So, we propose a duodecimal myriad system in Table 3²² replacing ten/hundred with dozen/gross. Larger numbers consist of uni(1), di(2), ter(3), tetra(4), penta(5), hexa(6), hepta(7), lli(0), on(+), and reciprocals are expressed by replacing on(+, positive power) with no(-, negative power).

Table 3 Duodecimal myriad system

decimal	dozenal	read as 'one-'	origin of prefix part	decimal	dozenal	read as 'one-'	origin of prefix part
12. ¹ .	10;	dozen	Old Norse	12. ⁻¹ .	U ^{-@1}	unino	Latin
12. ² .	100;	gross	Old French	12. ⁻² .	U ^{-@2}	dino	Greek
12. ³ .	1000;	doz gross		12. ⁻³ .	U ^{-@3}	terno	Latin
12. ⁴ .	1,0000;	myriad	Greek	12. ⁻⁴ .	U ^{-@4}	tetrano	Greek
12. ⁵ .	10,0000;	dozen myriad		12. ⁻⁵ .	U ^{-@5}	pentano	Greek
12. ⁶ .	100,0000;	gross myriad		12. ⁻⁶ .	U ^{-@6}	hexano	Greek
12. ⁷ .	1000,0000;	doz gross myriad		12. ⁻⁷ .	U ^{-@7}	heptano	Greek
12. ⁸ .	U	unillion		12. ⁻⁸ .	U ⁻¹	unillino	
12. ¹⁶ .	U ²	dillion		12. ⁻¹⁶ .	U ⁻²	dillino	
12. ²⁴ .	U ³	terllion		12. ⁻²⁴ .	U ⁻³	terllino	
12. ³² .	U ⁴	tetrallion		12. ⁻³² .	U ⁻⁴	tetrallino	
12. ⁴⁰ .	U ⁵	pentallion		12. ⁻⁴⁰ .	U ⁻⁵	pentallino	
12. ⁴⁸ .	U ⁶	hexallion		12. ⁻⁴⁸ .	U ⁻⁶	hexallino	
12. ⁵⁶ .	U ⁷	heptallion		12. ⁻⁵⁶ .	U ⁻⁷	heptallino	
12. ⁶⁴ .	U ^{10@}	unillillion		12. ⁻⁶⁴ .	U ^{-10@}	unillillino	
12. ¹²⁸ .	U ^{20@}	dillillion		12. ⁻¹²⁸ .	U ^{-20@}	dillillino	
...	

For example, 1_2345,6789; is read as 'one unillion two doz three gross four doz five myriad six doz seven gross eight doz nine'. The first 'one' should not be omitted. 'dozen' becomes abbreviated 'doz' before 'one' to 'eleven' or 'gross'. The expression 'Unillion to the power of *octal number*' is also used as exponential expression²³. For example, $1;2 \times U^{3@4}$ is read as 'one point two times unillion to the power of three point four'. '@4' can also be written 'H', in which case 'H' is read as 'and half'.

²⁰ See also footnote 33.

²¹ <http://en.wikipedia.org/wiki/-yllion> .

²² '@' is the octal radix point.

²³ Dr. Isaac Asimov made a similar proposal called 'T-formation'. See <http://www.isfdb.org/cgi-bin/title.cgi?62431> and <http://www.arvindguptatoys.com/arvindgupta/asimov-on-numbers.pdf> .

D. Tables

Table 4 Units with special names and symbols²⁴

ALL VALUES DECIMAL

Unit Category		Dimension	The Universal Unit Systems				
			with the Rydberg constant(u)		Harmonic System (h)		
Coherent	base units that are not natural units	length	m_u	272.102883 mm	m_h or hm^{25}	272.352206 mm	
		time	s_u	390.267520 ms	s_h or nc	390.625115 ms	
		energy	J_u	64.143275 mJ	J_h	64.084556 mJ	
		temperature ²⁶	K_u	58.441041 μK	K_h	58.387542 μK	
	base units that are natural units	plane angle	rad	$(2/\pi)$ arc sin(1)			
		logarithm	neper	log(e)			
		amount of substance	mol_n or N_A^{-1}	$mol / 6.02214076 \times 10^{23}$.			
		impedance	Ω_n or Z_P	$29.979245816 \Omega (=1sr/(\epsilon_0 c_0)^{27}$, is called ‘nohm’)			
	derived units of electromagnetic quantities	charge	C_u	28.896578 mC			
		electric current	A_u	74.043001 mA	A_h	73.975219 mA	
		field strength	E_u ^{18,28}	272.113988 mA/m	E_h	271.616007 mA/m	
		flux density	G_u ²⁸	390.283447 mC/m ²	G_h	389.569211 mC/m ²	
	derived units of dynamical quantities	mass	g_u	131.950082 g	g_h or $\ell\ell$	131.829289 g	
		power	W_u	164.357196 mW	W_h	164.056415 mW	
		force	N_u	235.731701 mN	N_h	235.300301 mN	
		Pressure	P_u	3.183843 Pa	P_h	3.172201 Pa	

²⁴ Please see also <http://www.asahi-net.or.jp/~dd6t-sg/univunit-e/units.pdf> and <https://www.tapataalk.com/groups/dozenonline/the-universal-unit-system-and-its-notaions-t371.html#p4080904> for details. A web-based unit converter is available at <http://hosi.org:8080/cgi-bin/conv.cgi>. This converter also teaches us the representation of units that belong to various unit systems.

²⁵ ‘harmon(hm)’, ‘nic(nc)’, ‘looloh($\ell\ell$)’, and ‘nohm(Ω_n)’ constitutes a quartet. These are the alias for common use.

²⁶ The unit of thermodynamic temperature has been changed. The new unit is one-1,0000;th of the old unit in the paper <http://dozenal.com> along with the introduction of the Earth local extension.

²⁷ If we adopt the elementary charge as one of the definition constants, Ω_u is used in substitution for Ω_n .

²⁸ The unit symbol E(Ørsted) and G(Gauß) are associated with the units of CGS unit system. In this paper, we adopt the metric unit names named after the scientists' name as it is. However, an alternative proposal to replace them with the names of the goddesses with the same initials have (i.e., Joule→Juno, Watt→Walküre, Newton→Nereide, Pascal→Polymnia, Coulomb→Clio, Ampere→Aoide, Ørsted→Erato, Gauß→Gaea, Kelvin→Korē) also been proposed.

Non-coherent	defining constants	wave number	R_∞	10,973,731.56816/m (is called ‘Rydberg’)
		velocity	c_0	299,792,458 m/s (defined, and is called ‘light’)
		action	\hbar	$6.62607015 \times 10^{-34} \text{J}\cdot\text{s}/2\pi$ (is called ‘quantum’)
		heat capacity	k_B	$1.380649 \times 10^{-23} \text{J/K}$ (is called ‘Boltzmann’)
Non-coherent	supplementary constants	the total solid angle of a hypersphere	Ω_k	$\frac{2\pi^{\frac{k+1}{2}}}{\Gamma(\frac{k+1}{2})} \text{ rad}^k$ $k=0,1,2$ $\Omega_0=2$ $\Omega_1=2\pi \text{ rad}$ (cycle) $\Omega_2=4\pi \text{ sr}$ (turn)
		logarithm of an integer	f_k	$\log(2^k)$ $k=1(\text{bit}), d(\text{figure}), 4(\text{nibble}), 8(\text{byte}), \dots$ $d=\log_2(12.)$
		amount of substance	mol_u	132.007620 mol (=12. ²⁴ / N_A)
		elementary charge	e	$1.6021766340 \times 10^{-19} \text{C}$ $(= \sqrt{\frac{\alpha \hbar}{\Omega_n}})$

Table 5 Physical, material and astronomical constants²⁹

ALL VALUES DOZENAL

Constant Symbols and Name (UNDERLINE INDICATES CONSTANT MAINTAINS SAME VALUE BETWEEN SYSTEMS u AND h)		Constant Value expressed by the Universal Unit Systems		Expone nt N of \times $10;^N$	Unit Symbol (u and h suffixes omitted)
		with the Rydberg constant (u)	Harmonic System (h)		
R_∞	Rydberg constant	1	1;00170000	6;	Ω_1/m
c_0	<u>the speed of light in vacuum</u>	1		8;	m/s
\hbar	<u>quantum of action</u>	1		-26;	J s
k_B	<u>Boltzmann constant</u>	1		-20;	J/K
N_A	<u>Avogadro constant</u>	1		20;	mol^{-1}
R	<u>gas constant</u>	1		0;	J/(mol K)
u	unified atomic mass unit	1;0009060E	1;00240733	-20;	g^{30}
a_B	Bohr Radius	1;005E85688	1;00447X742	-9;	m
α	<u>fine structure constant</u>	1;07399404XX		-2;	-
e	<u>elementary charge</u>	1;0374439E14		-14;	C
m_e	electron mass	0;E469221744	0;E48324X199	-23;	g
σ	<u>Stefan-Boltzmann constant</u>	1;E82E28		-1E;	$\text{W}/(\text{m}^2\text{K}^4)$

²⁹ If CODATA (2018) values are required, see <http://physics.nist.gov/cuu/Constants/index.html> .

³⁰ Because g_u is approximately 100;¹⁰; u , I add alias name ‘looloh’ (lú:lou/əu) to g_h .

m_G	gravitic meter $(\sqrt{2E}; l_P)$	1;00186	1;00016	-27;	m
l_P	Planck length	2;0445E	2;04134	-28;	m
F_P	Planck force $(\hbar c_0 / l_P^2)$	2;XE206	2;XEE32($\neq 2;E$) ³¹	35;	N
G	Newtonian constant of gravitation (c_0^4 / F_P)	4;15768	4;14663	-X;	$(m^4/s^4)/N$
θ_W	<u>weak mixing angle</u>	E;304		-2;	Ω_1
V_m	molar volume of an ideal gas under standard conditions	1;02X469	1;025665	2;	m^3/mol
	black-body radiation at the ice point	0;EX2466	0;EX8784	2;	W/m^2
	maximum density of water	1;088183	1;092X47 ($\neq 15;/14;$)	2;	g/m^3
	density of ice at the ice point	0;E7E9	0;E85E	2;	g/m^3
	specific heat of water ³²	0;6052	0;6045 ($\neq 1/2$)	0;	$J/(g K)$
	surface tension of water at 25°C	0;EE68	0;EEE4	-1;	N/m
atm	standard atmosphere	1;65008E	1;659967 ($\neq 1;66$)	4;	P
g_n	standard gravitational acceleration	5;5X54XE9	5;5E21264 ($\neq E;/2$)	0;	m/s^2
r_E	gravitational radius of Earth	2;41E8982X0X	2;418030652	-2;	m
au	astronomical unit	8;X67575535	8;X55509X31	X;	m
	<u>astronomical unit</u>	9;E91731X53		-3;	$c_0 s_E$ day

Table 6 Power prefixes

name	symbol	Plain text	value	name	symbol	Plain text	value
dirac ³³		D	10;				
hyper		H	10;⁴	sub		s	10;⁻⁴
cosmic	+	_+	10; ⁸ (=U)	atomic	-	_-	U ⁻¹
di-cosmic	2+	_2+	U ²	di-atomic	2-	_2-	U ⁻²
ter-cosmic	3+	_3+	U ³	ter-atomic	3-	_3-	U ⁻³
tetra-cosmic	4+	_4+	U ⁴	tetra-atomic	4-	_4-	U ⁻⁴
penta-cosmic	5+	_5+	U ⁵	penta-atomic	5-	_5-	U ⁻⁵
hexa-cosmic	6+	_6+	U ⁶	hexa-atomic	6-	_6-	U ⁻⁶
hepta-cosmic	7+	_7+	U ⁷	hepta-atomic	7-	_7-	U ⁻⁷

³¹ If this is expressed as 2;E, the error from CODATA (2018) becomes -6;61(-6.51) times standard deviation.

³² This corresponds to the definition of the thermodynamic calorie.

³³ ‘dirac’ is only used when expressing the unit of the Gravitic System with the Harmonic System. (i.e., gravitic meter = tetra-atomic dirac harmon, gravitic second = penta-atomic dirac nic, gravitic gram = atomic dirac looloh)

Table 7 Examples of natural scale quantity representation ³⁴

quantity	symbol	value	refer to
2E; penta-cosmic Newton	2E; ₅₊ N	2E;×U ⁵ [harmonic] Newton	the Planck force
6;di-cosmic nic	6; ₂₊ nc	6;×U ² [harmonic]nic[second]	the age of the universe
cosmic hyper bit [Boltzmann]	+Hf ₁ [k _B]	U ^{1@4} log2 ¹ [Boltzmann]	1.01 Tera Byte(=2 ⁴³ ·bit)
cosmic harmon	+hm	U ¹ harmon[ic meter]	the speed of light in vacuum
unino atomic harmon	0;1.hm	U ^{-1@1} harmon[ic meter]	the Bohr radius
di-atomic Coulomb	₂ .C	U ⁻² [universal] Coulomb	the elementary charge
di-atomic effective Watt ³⁵	₂ .W _e	U ⁻² [harmonic]effective Watt	a photon power (540.THz)
ter-atomic looloh	₃ .ℓℓ	U ⁻³ looloh	the unified atomic mass unit
2; tetra-atomic harmon	2; ₄ .hm	2;×U ⁻⁴ harmon[ic meter]	the Planck length

Table 8 The Earth local extension for the Harmonic Universal Unit System

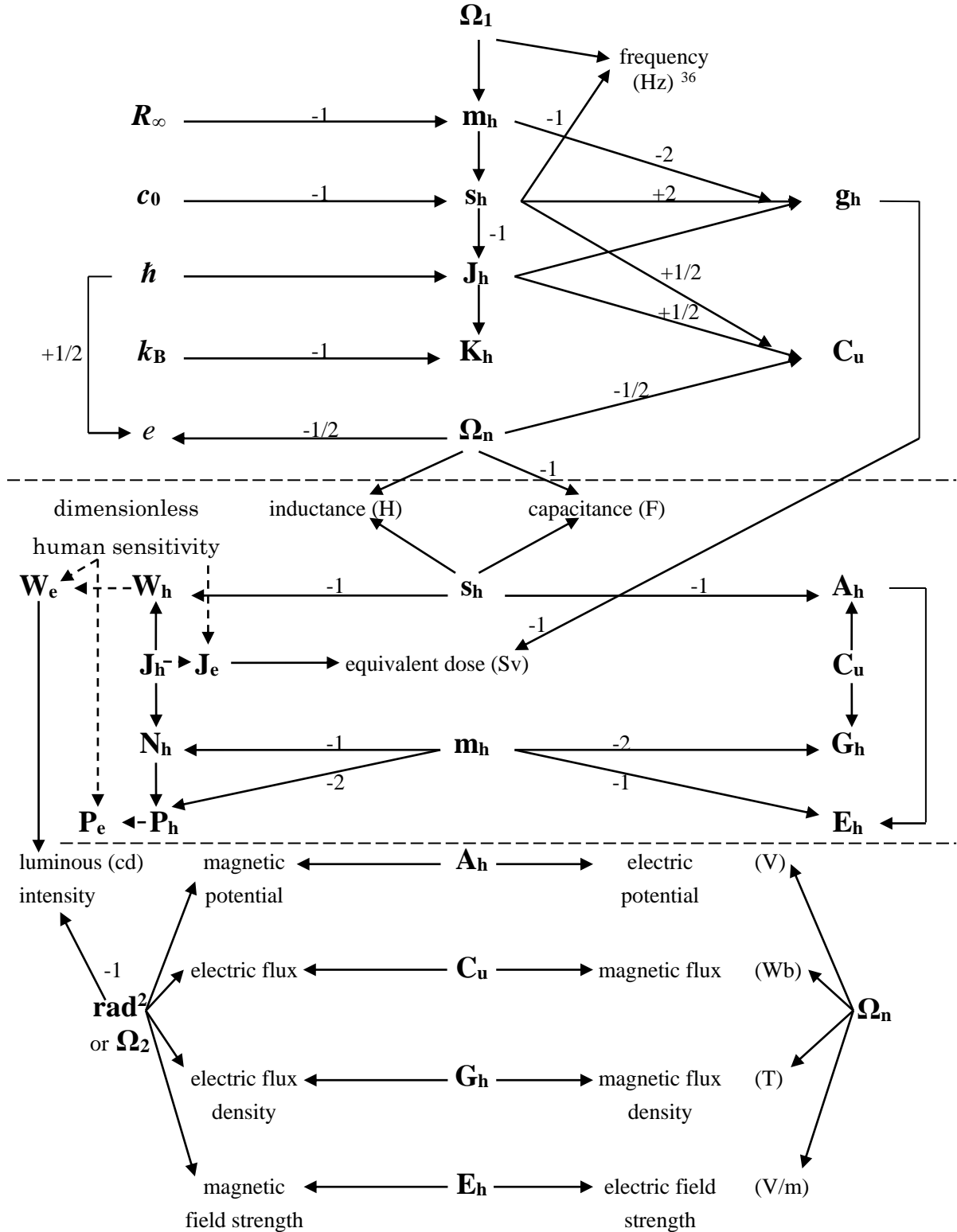
category		name / description	symbol	plain text	value
Non-coherent calendar time	units	clock	c	(terno clock→tc)	2 ⁻⁷ day
		day	d	(terno day→td)	1 Ω ₁ 'day' corresponds to 86,400. s at the beginning of year 1900.
		year	y or a		365.days 31.clocks
		span (or octal century)	span or “^”		64. years
Non-coherent unit and constants		difference between thermodynamic temperature and 118,2354; K _h (≐ -74.36°C) approximate formula $\text{°C} = \frac{1E}{17}; \text{°H} - 62; 4$ $\text{°H} = \frac{17}{1E}; \text{°C} + 51; 5$	°H	deg H	1,0000; K _h (≐ 1.210724 K ≐ 23./19. K)
					100; 0000°H is 99.9839 °C
					78; 0000°H is 37.0262°C
					61; 0000°H is 14.0224°C
					51; 5026°H is 0.0000°C
		99.9839 °C is the boiling point of water at the standard atmosphere.			
supplementary constants		the gravitational acceleration of the Earth (is called 'gee [of Earth]')	g _E	g_E or gee	5;611X615 harmon/nic ² g _E is defined as c ₀ ² r _E (m _E rad) ⁻²
		the rotation period of the Earth (is called '[Earth] solar') at the beginning of year 1900.	s _E	s_E or solar	0;EEEEEE15336X nic/terno clock (This should be 'coordinated'. ¹⁶)
		the meridian length of the Earth (is called '[Earth] meridian')	m _E	m_E or meridian	4124,216E; harmon/Ω ₁

³⁴ The part enclosed with '[']' can be omitted in Table 7 and Table 8.

³⁵ Units for quantity weighted by dimensionless human sensitivity are indicated by 'effective'.

W_e corresponds to 1;di-cosmic photon energy(540.THz) / nic and 115.667212 lumen.

E. Relation of Units and Dimensions



³⁶ The units enclosed with '()' are units of SI.

F. Ratios of fundamental physical constants

F.1. The fine structure constant and the elementary charge

The fine structure constant, α , a dimensionless quantity, was originally introduced for the purpose to explain the fine structure spectral emission lines.

$$\alpha = \frac{e^2}{4\pi\epsilon_0 c_0 \hbar} \quad (\text{X})$$

By multiplying both sides of Eq. (X) by $\frac{c_0 \hbar}{r^2}$, we get

$$\alpha \frac{c_0 \hbar}{r^2} = \frac{1}{4\pi\epsilon_0} \frac{e^2}{r^2} \quad (\text{E})$$

The right side of Eq. (E) expresses the Coulomb force acting between two elementary charges (i.e., the electrical charge of an electron) separated by a distance of r . The left side indicates that this force is proportional to $\frac{c_0 \hbar}{r^2}$ by a factor of α . For this reason, the fine structure constant, α , can be interpreted as a dimensionless quantity that represents the strength of electromagnetic interaction.

The value of the fine structure constant, α , is close to 10^{-2} (12.⁻²).

DOZENAL

$$\alpha = \frac{1}{\text{E5;0522588}} = 1;07399404\text{E} \times 10^{-2}$$

DECIMAL

(10;)

$$\alpha = \frac{1}{137.03599908} = 1.050818770 \times 12^{-2}$$

Therefore, the ratio of the elementary charge, e , and “the dimensioned quantity of charge, which is derived from the speed of light in vacuum, c_0 , and the quantum of action, \hbar ” is:

DOZENAL

$$\alpha^{\frac{1}{2}} = \frac{e}{\sqrt{4\pi\epsilon_0 c_0 \hbar}} = 1;0374439\text{E}3 \times 10^{-1}$$

DECIMAL

(11;)

$$\alpha^{\frac{1}{2}} = \frac{e}{\sqrt{4\pi\epsilon_0 c_0 \hbar}} = 1.025094518 \times 12^{-1}$$

F.2. The Rydberg constant and the Bohr radius

The deviation of the fine structure constant, α , from an integer power of twelve is nearly the same as the deviation of 4π from twelve.

DOZENAL

$$4\pi = 1;069683171 \times 10;^1 = \frac{1}{\text{E5;6150822}} \times 10;^3$$

DECIMAL (12;)

$$4\pi = 1.047197551 \times 12^1 = \frac{1}{137.5098708} \times 12^3$$

The ratio of the Bohr radius, a_B , and “the dimensioned quantity of length, $L=R_\infty^{-1}$, where R_∞ is the Rydberg constant” is:

DOZENAL

$$\frac{a_B}{L} = \frac{\alpha}{4\pi} \text{ (strict)} = 1;005E85688 \times 10;^{-3}$$

DECIMAL (13;)

$$\frac{a_B}{L} = \frac{\alpha}{4\pi} \text{ (strict)} = 1.003458009 \times 12^{-3}$$

F.3. The electron mass and the unified atomic mass unit

The ratio of the mass of an electron, m_e , and “the dimensioned quantity of mass, M , which is derived from L , the speed of light in vacuum, c_0 , and the quantum of action \hbar ,”

$$M = \frac{\hbar}{c_0 L}, \quad (14;)$$

is:

DOZENAL

$$\frac{m_e}{M} = \frac{4\pi}{\alpha^2} \text{ (strict)} = 0;E4692217 \times 10;^5$$

DECIMAL (15;)

$$\frac{m_e}{M} = \frac{4\pi}{\alpha^2} \text{ (strict)} = 0.948359447 \times 12^5$$

The ratio of the mass of an electron, m_e and the unified atomic mass unit, u , is:

DOZENAL

$$\frac{m_e}{u} = \frac{1}{107X;X7E4} = \frac{4\pi}{\alpha^2} \times 0.EEE2E66 \times 10;^{-8}$$

DECIMAL (16;)

$$\frac{m_e}{u} = \frac{1}{1822.8885} = \frac{4\pi}{\alpha^2} \times 0.9995641 \times 12^{-8}$$

This ratio corresponds to the ratio of typical nuclear energy and chemical energy. The deviations of ratio Eq. (15;) and ratio Eq. (16;) from multiples of an integer power of twelve are near to the same magnitude. Therefore:

DOZENAL

$$\frac{u}{M} = 1;0009060E \times 10;^8$$

DECIMAL

$$\frac{u}{M} = 1.00043606 \times 12^8 \quad (17;)$$

F.4. The Planck length

The ratio of the general expression of the Planck length, $\sqrt{\frac{G\hbar}{c_0^3}}$, and L is close to 2 when factors of multiples of an integer power of twelve are eliminated.

DOZENAL

$$\sqrt{\frac{G\hbar}{c_0^3}}/L = 2 \times 1;0222E \times 10;^{-22}$$

DECIMAL

(18;)

$$\sqrt{\frac{G\hbar}{c_0^3}}/L = 2 \times 1.01519 \times 12^{-26}$$

Taking the expression $\sqrt{\frac{G\hbar}{c_0^3\alpha}}$, which has been adjusted³⁷ by the fine structure constant, α , in order to express the tensile force in a superstring in terms of the Planck length, the ratio of the adjusted Planck length and L then becomes:

DOZENAL

$$\sqrt{\frac{G\hbar}{c_0^3\alpha}}/L = 2 \times 0;EX737 \times 10;^{-21}$$

DECIMAL

(19;)

$$\sqrt{\frac{G\hbar}{c_0^3\alpha}}/L = 2 \times 0.99034 \times 12^{-25}$$

The Gravitic Universal Unit System uses 140.0 to approximate $\alpha^{-1}(=137.03599908)$. Because 1,0017;(20,755.=35. \times 593.) is divisible with 2E;(35.), we can approximate G by Eq.(1X;) about 6.51 times standard deviation error of CODATA(2018):

$$G \doteq \frac{(5 \times 7)^2 \times 415;^2 c_0^3}{5 \times 7 \times \hbar R_0^2} \times 10;^{-4X} = \frac{5 \times 7 \times 415;^2 c_0^3}{\hbar R_0^2} \times 10;^{-4X} \quad (1X;)$$

³⁷ See E. Witten, 'Reflections on the fate of spacetime' p. 24. in April 11X4;(1996.) *Physics Today*.