Exact Formulas of the Age of the Universe and of the Gravitational Constant dependent on Physical Constants

Version 3

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Abstract:

The british Physicist Paul Dirac (1902 - 1984) founded the Large Number Hypothesis[1], which handles with strange relations using numbers in order of magnitude 10^{40}. Also the german Physicist, Mathematician and Philosopher Hermann Weyl (1885 - 1955) was occupied with relations of High Order Numbers. In this report Formulas are presented, which give the Age of the Universe and the Gravitational Constant within their Tolerance Range both in dependence on Physical Constants.

Equation for the Age of the Universe:

The Age of the Universe is given to $13{,}787 \pm 0{,}02 \cdot 10^9$ years[2].

The Age of the Universe Age_{Univ} in SI-Unit s is: $13{,}787 \cdot 10^9 \cdot 3600 \cdot 24 \cdot 356{,}256 = 4{,}35092 \cdot 10^{17}$ s.

The maximal allowable relative tolerance range is: $(13{,}787 \pm 0{,}02) / 13{,}787$

that means a relative tolerance range from 0,99855 to 1,00145

The Large Number Equation LN_T, which is known since nearly 100 years, is written by use of the Age of the Universe, the Light Velocity c_L[3.1] and the Electron Radius r_e[3.2] to:

$$LN_T = Age_{Univ} \cdot c_L / r_e = 4{,}6288 \cdot 10^{40} \qquad \text{(LN-T1)}$$

A pretty simple, but harmonic Approximation of the quantity LN_T can be given by the following Equation LN_{TAppr}, at which the Fine Structure Constant α[3.3] and the Circle Figure π are used:

$$LN_{TAppr} = (4\,\pi / \alpha)^{4\pi} = 4{,}6274 \cdot 10^{40} \qquad \text{(LN-T2)}$$

The values of the used quantities Light Velocity c_L, Electron Radius r_e and Fine Structure Constant α can be taken from the section Used Data of Physical Constants at page 5.

The Equation for the Approximation Age_{Univ_Appr} of the Universe Age is given by Equating of Equations (LN-T1) and (LN-T2) and by conversion of the Equation it can be written to:

$$Age_{Univ\_Appr} = (4\,\pi / \alpha)^{4\,\pi} \cdot r_e / c_L = 4{,}3496 \cdot 10^{17}\ \text{s} = 13{,}783 \cdot 10^9\ \text{a} \qquad \text{(Age-Appr)}$$

The ratio of the calculated value Age_{Univ_Appr} to the set value is:

$13{,}783 / 13{,}787 = 0{,}99969$

The calculated value Age_{Univ_Appr} is far within the tolerance range of the set value[2] of the Universe Age. If one uses the terms "$1{,}000017 \cdot (4\,\pi)$" or "$0{,}999988 \cdot (4\,\pi)$" at the basis as well as at the exponent of Equation (Age-Appr) instead of the term "$4\,\pi$", the result is outside the tolerance range of the set value.

The term "$4\,\pi$" can also be observed at the Equation of the Magnetic Field Constant μ_0[3.5]:

$$\mu_0 = 4\,\pi \cdot (m_e \cdot r_e) / e^2$$

See values of the Magnetic Field Constant μ_0[3.5], the Electron mass m_e[3.6], the Electron Charge e[3.7] at page 5 at the section Used Data of Physical Constants.

The term "$4\,\pi$" is also used at the Equation (G-EK) of Dr. Endre Kerezturi at page 2.

The Approximation LN_{TAppr} of the Large Number LN_T isn't too difficult to find. One takes an Equation with the form $(A \cdot B)^A$ preferably for the Quantities with relatively big tolerance range, as for example the Gravitational Constant G or the Age of Universe. One can determine quite fast the exact value of the quantity A by use of the tool "Target Value Search", which is offered by most spreadsheet programs. The quantity B is in the case of Equation (Age-Appr) the Inverse of the Fine Structure Constant α.

By this circumstance it may possible, that Equation (LN-T2) was already found by someone else, but who is unknown to the author. If this person or group had found Equation (LN-T2) before the time, when the author of this report found the Equation (LN-T2), this person or group naturally can claim its performing.

Large Numbers for the Gravitational Constant G:

The value of Gravitational Constant G is given according literature [3.8] to:

$$G = (6{,}67430 \pm 0{,}00015) \cdot 10^{-11} \; m^3 \, kg^{-1} \, s^{-2} \qquad \text{(LN-G)}$$

In the following some Large Number LN_G are presented by use of Physical Constants and with the goal to eliminate the SI-Units of the Gravitational Constants:

$$LN_{G1} = c_L^2 \cdot r_e / (m_e \cdot G) = 4{,}165609 \cdot 10^{42} \qquad \text{(LN-G1)}$$

$$LN_{G2} = c_L^2 \cdot r_p / (m_p \cdot G) = 6{,}769658 \cdot 10^{38} \qquad \text{(LN-G2)}$$

$$LN_{G3} = c_L^3 \cdot Age_{Univ\_Appr} / (m_e \cdot G) = 1{,}927584 \cdot 10^{83} \qquad \text{(LN-G3)}$$

$$LN_{G4} = c_L^3 \cdot Age_{Univ\_Appr} / (m_p \cdot G) = 1{,}049795 \cdot 10^{80} \qquad \text{(LN-G4)}$$

See value of the Proton Radius[4] r_p and the Proton Mass[5] m_p at page 5 at the section Used Data of Physical Constants.

Equation of Dr. Endre Kereszturi:

There is a spectacular Equation (G-EK) for the Gravitational Constant G of Dr. Endre Kereszturi[6]. The result with extra added Units (Meter $\mathbf{m}^{-5}$ and second **s**) is very exact referring the tolerance:

$$G_{EK} = h^5 \cdot \alpha^2 / [(c_L^2 \cdot m_e^6) \cdot (4\pi)^3] \cdot \mathbf{m^{-5}\, s} = 6{,}6743017 \cdot 10^{-11} \; m^3 \, kg^{-1} \, s^{-2} \qquad \text{(G-EK)}$$

See the value of the Plancks Constant h[3.9] at page 5 at the section Used Data of Physical Constants.
Remarkable: Equation (G-EK) contains the term "4 π", which is used two times at Equation (LN-T2)!
[A short Insert: dear Scientists, do you really think, that the result of Equation (G-EK) is random? This Equation contains the relatively big exponent values 5 and 6 for the Physical Constants h and m_e, in the whole the sum of exponents is 18. And the values of the corresponding basis (the Physical Constants) are highly exact, by that it is very remarkable, that one gets this excellent result for the Gravitational Constant by combining four Physical Constants with full number exponents, even if missing units have to be added!].

The following Equation (G-EK0) is introduced with the goal to avoid working with extra added Units:

$$G_{EK0} = h^5 \cdot \alpha^2 / [(c_L^2 \cdot m_e^6) \cdot (4\pi)^3] = 6{,}6743017 \cdot 10^{-11} \; m^8 \, kg^{-1} \, s^{-3} \qquad \text{(G-EK0)}$$

To solve the missing units "$\mathbf{m}^{-5}$ **s**" at Equation (G-EK0), two kinds of Large Numbers LN_{G_EK} are introduced. The first kind of the Large Numbers possesses the just mentioned units "$\mathbf{m}^{-5}$ **s**":

$$LN_{G\_EK1} = 1 / (c_L \cdot r_e^4) = 5{,}2899568 \cdot 10^{49} \; m^{-5} \, s \qquad \text{(LN-G\_EK1)}$$

$$LN_{G\_EK2} = 1 / (c_L \cdot r_e^3 \cdot r_p) = 1{,}7727809 \cdot 10^{50} \; m^{-5} \, s \qquad \text{(LN-G\_EK2)}$$

$$LN_{G\_EK3} = 1 / (c_L \cdot r_e^2 \cdot r_p^2) = 5{,}9409787 \cdot 10^{50} \; m^{-5} \, s \qquad \text{(LN-G\_EK3)}$$

$$LN_{G\_EK4} = 1 / (c_L \cdot r_e \cdot r_p^3) = 1{,}9909526 \cdot 10^{51} \; m^{-5} \, s \qquad \text{(LN-G\_EK4)}$$

$$LN_{G\_EK5} = 1 / (c_L \cdot r_p^4) = 6{,}6721202 \cdot 10^{51} \; m^{-5} \, s \qquad \text{(LN-G\_EK5)}$$

$$LN_{G\_EK6} = 1 / (c_L \cdot r_e^{-1} \cdot r_p^5) = 2{,}2359742 \cdot 10^{52} \; m^{-5} \, s \qquad \text{(LN-G\_EK6)}$$

The second kind of the Large Numbers takes the values of the just presented Equations, but these Large Numbers are reduced to values without any SI-Units:

$$LN_{G\_EK1\#} = LN_{G\_EK1} \cdot m^5 \, s^{-1} = 5{,}2899568 \cdot 10^{49} \qquad \text{(LN-G\_EK1\#)}$$

$$LN_{G\_EK2\#} = LN_{G\_EK2} \cdot m^5 \, s^{-1} = 1{,}7727809 \cdot 10^{50} \qquad \text{(LN-G\_EK2\#)}$$

$LN_{G\_EK3\#} = LN_{G\_EK3} \cdot m^5 \, s^{-1} = 5{,}9409787 \cdot 10^{50}$ (LN-G_EK3#)
$LN_{G\_EK4\#} = LN_{G\_EK4} \cdot m^5 \, s^{-1} = 1{,}9909526 \cdot 10^{51}$ (LN-G_EK4#)
$LN_{G\_EK5\#} = LN_{G\_EK5} \cdot m^5 \, s^{-1} = 6{,}6721202 \cdot 10^{51}$ (LN-G_EK5#)
$LN_{G\_EK6\#} = LN_{G\_EK6} \cdot m^5 \, s^{-1} = 2{,}2359742 \cdot 10^{52}$ (LN-G_EK6#)

The Equations for the Gravitational Constant G are written in the following:

$G_{EK1} = G_{EK0} \cdot LN_{G\_EK1} / LN_{G\_EK1\#}$ (G-EK1)
$G_{EK2} = G_{EK0} \cdot LN_{G\_EK2} / LN_{G\_EK2\#}$ (G-EK2)
$G_{EK3} = G_{EK0} \cdot LN_{G\_EK3} / LN_{G\_EK3\#}$ (G-EK3)
$G_{EK4} = G_{EK0} \cdot LN_{G\_EK4} / LN_{G\_EK4\#}$ (G-EK4)
$G_{EK5} = G_{EK0} \cdot LN_{G\_EK5} / LN_{G\_EK5\#}$ (G-EK5)
$G_{EK6} = G_{EK0} \cdot LN_{G\_EK6} / LN_{G\_EK6\#}$ (G-EK6)

The mathematical art is finding - if necessary - appropriate, reasonable Approximations for the Large Numbers $LN_{G\_EK1\#}$ to $LN_{G\_EK6\#}$. Furthermore the results of the Equations (G-EK1) to (G-EK6) have to be within the tolerance range of the Gravitational Constant G.
This was already partly performed in the author's report [7] (see page 6 and 7), although at that time the Large Number Hypothesis was not yet known to the author.

An example of a Large Number Term for the Gravitational Constant G, but which lies outside the tolerance range, might be the following Equation:

$LN_{G\_EK6a} = 0{,}99 \cdot (5\,\pi / \alpha)^{5\pi} = 2{,}236469 \cdot 10^{52}$ (LN-G_EK6a)

$G_{EK6a} = G_{EK0} \cdot LN_{G\_EK6} / LN_{G\_EK6a} =$
$= 6{,}6743017 \cdot 10^{-11} \, m^8 \, kg^{-1} \, s^{-3} \cdot (2{,}2359742 \cdot 10^{52} \, m^{-5} \, s) / (2{,}236469 \cdot 10^{52}) =$
$= 6{,}67283 \cdot 10^{-11} \, m^3 \, kg^{-1} \, s^{-2}$ (G-EK6a)

Result of Equation G_{EK6a} lies below the lower value (= $6{,}67415 \cdot 10^{-11} \, m^3 \, kg^{-1} \, s^{-2}$) of the tolerance range of the Gravitational Constant G, that means it lies outside the tolerance range of G.

The ratio "G_{EK6a} / G" is: $6{,}67283 \cdot 10^{-11} \, m^3 \, kg^{-1} \, s^{-2} / 6{,}67430 \cdot 10^{-11} \, m^3 \, kg^{-1} \, s^{-2} = 0{,}99978$

If the value $r_{p\#}$ "$=8{,}40833 \cdot 10^{-16}$ m", which lies far within the tolerance range of the Proton Radius r_p [$=(8{,}4087 \pm 0{,}0039) \cdot 10^{-16}$ m] according to Pohl[4], is set instead of the Set Radius r_p at Equation LN_{G_EK6}, the result of Equation (G-EK6b) corresponds closely to set value of the Gravitational Constant G.

$LN_{G\_EK6b} = 1 / [c_L \cdot r_e^{-1} \cdot (8{,}40833 \cdot 10^{-16} \, m)^5] = 2{,}236469 \cdot 10^{52} \; m^{-5} \, s$ (LN-G_EK6b)
$G_{EK6b} = G_{EK0} \cdot LN_{G\_EK6b} / LN_{G\_EK6a} = 6{,}674295 \cdot 10^{-11} \, m^3 \, kg^{-1} \, s^{-2}$ (G-EK6b)

Result value of Equation (G-EK6b) corresponds very close to the set value G of the Gravitational Constant (= $6{,}67430 \cdot 10^{-11} \, m^3 \, kg^{-1} \, s^{-2}$) by use of the adapted Proton Radius $r_{p\#}$ (=$8{,}40833 \cdot 10^{-16}$ m).

The term 0,99 of Equation (LN-G_EK6a) consists of the figures 0,9 and 1,1. And these figures - the 9 and 11 in combination with 10-powers - are named in the author's report [7] (see page 2) as helpful figures performing Approximations of Physical Constants and of Data of Earth, Moon and Sun.

There is another exact approximation by use of the Kereszturi-Formula, which fits to the set value of the Proton Radius r_p:

$LN_{G\_EK6c} = [\pi \cdot r_p / r_e)]^{1/(2\pi)} \cdot (5\,\pi / \alpha)^{5\pi} = 2{,}2359538 \cdot 10^{52}$ (LN-G_EK6c)

$G_{EK6c} = G_{EK0} \cdot LN_{G\_EK6} / LN_{G\_EK6c} = h^5 \cdot \alpha^2 / [(4\,\pi)^3 \cdot c_L^3 \cdot m_e^6 \cdot (r_e^{-1} \cdot r_p^5) \cdot LN_{G\_EK6c}] =$
$= 6{,}6743017 \cdot 10^{-11} \, m^8 \, kg^{-1} \, s^{-3} \cdot (2{,}2359742 \cdot 10^{52} \, m^{-5} \, s) / (2{,}2359538 \cdot 10^{52}) =$
$= 6{,}67436 \cdot 10^{-11} \, m^3 \, kg^{-1} \, s^{-2}$ (G-EK6c)

Result value of Equation (G-EK6c) is within the tolerance range of the Gravitational Constant G, it uses only 40% [= (0,00006 / 0,00015) · 10^{-11} m^3 kg^{-1} s^{-2}] of the upper limit of this tolerance.

If one adapt Equation (LN-G_EK6a) by inserting an Exponent for the Figure 0,99, one gets an exact result for the Gravitational Constant. Please see the following Formula:

$$LN_{G\_EK6d} = 0{,}99^{1/(0{,}99 \cdot 0{,}99)} \cdot (5\,\pi / \alpha)^{5\pi} = 2{,}2360122 \cdot 10^{52} \qquad \text{(LN-G\_EK6d)}$$

$$G_{EK6d} = G_{EK0} \cdot LN_{G\_EK6} / LN_{G\_EK6d} =$$
$$= 6{,}6743017 \cdot 10^{-11}\ m^8\ kg^{-1}\ s^{-3} \cdot (2{,}2359742 \cdot 10^{52}\ m^{-5}\ s) \ / \ (2{,}2360122 \cdot 10^{52}) =$$
$$= 6{,}674188 \cdot 10^{-11}\ m^3\ kg^{-1}\ s^{-2} \qquad \text{(G-EK6d)}$$

Result of Equation G_{EK6d} lies within the tolerance range of the Gravitational Constant G, it uses nearly 75% of the lower tolerance limit.
Term "0,99 · 0,99" delivers the value 0,9801. The figures 9801 and 396 (= 4 · 99) are used at the Serie Formula[8] for the Circle Figure π of the Indian Mathematician Srinivasa Ramanujan[8] (1887 - 1920).

Electrical and Gravitational Forces:

The Electrical Force (absolute value) between a Proton and an Electron is determined to:

$$F_{e\_pe} = e \cdot |-e| \cdot \mu_0 \cdot c_L^2 / [4\,\pi \cdot (r_e + r_p)^2] = m_e \cdot r_e \cdot c_L^2 / (r_e + r_p)^2 = 17{,}23385\ N \qquad \text{(F1)}$$
$$\text{with} \quad \mu_0 = 4\,\pi \cdot m_e \cdot r_e / e^2$$

The Gravitational Force between a Proton and a Electron is determined to:

$$F_{G\_pe} = G \cdot m_e \cdot m_p / (r_e + r_p)^2 = 7{,}59649 \cdot 10^{-39}\ N \qquad \text{(F2)}$$

The Ratio "$LN_{F\_pe} = F_{e\_pe} / F_{G\_pe}$", which also can be seen as a Large Number, is written to:

$$LN_{F\_pe} = F_{e\_pe} / F_{G\_pe} = 2{,}268661 \cdot 10^{39} \qquad \text{(LN-F1)}$$

The Ratio "F_{e_pe} / F_{G_pe} " combined with the Large Number LN_{TAppr} delivers the following Equations:

$$LN_{TAppr} \cdot LN_{F\_pe} = 4{,}6274 \cdot 10^{40} \cdot 2{,}268661 \cdot 10^{39} = 1{,}0498 \cdot 10^{80} = c_L^3 \cdot Age_{Univ\_Appr} / (m_p \cdot G) \ [\approx 10^{80}]$$

$$LN_{TAppr} \cdot LN_{F\_pe} = 4{,}6274 \cdot 10^{40} / (2{,}268661 \cdot 10^{39}) = 20{,}3970$$

Another remarkable and helpful Relations:

$$Rel_1 = [5\,\pi / (4\,\pi/\alpha)^{4\pi}] \cdot [(r_e + r_p) / r_e] \cdot LN_{F\_pe} = 0{,}999914 \quad [\approx 1] \qquad \text{(Rel1)}$$

$$Rel_2 = [1 - \alpha/(3\,\pi)]^{1/(3\pi)} = 0{,}9999178 \quad [\approx Rel_1] \qquad \text{(Rel2)}$$

By Equalization of the left parts of the two upper Equations one gets an exact Formula for the Gravitational Constant G, which is derived by the Electrical and Gravitational Forces (see Equations F1 and F2) and which lies far within its tolerance range:

$$G_{F1} = \{(5\,\pi) \cdot (4\,\pi/\alpha)^{-4\pi} \cdot [1 - \alpha/(3\,\pi)]^{-1/(3\pi)}\} \cdot c_L^2 \cdot (r_e + r_p) / m_p = 6{,}674276 \cdot 10^{-11}\ m^3\ kg^{-1}\ s^{-2} \qquad \text{(G-F1)}$$

Result of Equation (G-F1) uses only 16% of the lower Tolerance Range of the Gravitational Constant G. One considers, that the figures 3, 4 and 5 belong to the terms with the Circle Figure π.

There is another Formula with Relation (Rel3), which fits very good to Equation (G-F2):

$$Rel_3 = [1 - \alpha \cdot (3\,\pi)]^{1/(36\pi)} = 0{,}9993702 \qquad \text{(Rel3)}$$

$$G_{F2} = \{(5\,\pi) \cdot (4\,\pi/\alpha)^{-4\pi} \cdot [1 - \alpha \cdot (3\,\pi)]^{-1/(36\pi)}\} \cdot c_L^2 \cdot (r_e + r_p) / (m_e + m_p) =$$
$$= 6{,}674298 \cdot 10^{-11}\ m^3\ kg^{-1}\ s^{-2} \qquad \text{(G-F2)}$$

Result of Equation (G-F2) uses only 1,2% of the lower Tolerance Range of the Gravitational Constant G. Please look at figure 36, which is also used as an exponent part at the next Equation (G-F3).

At the next formula figure 36 (= 4 · 9) is used besides the figure 99 (= 9 · 11). Last one is also observable at Equations (LN-G_EK6a) and (LN-G_EK6d) by the form 0,99:

$$G_{F3} = \{99^{-1} \cdot (4\pi/\alpha)^{-4\pi} \cdot [36 \cdot r_p / r_e]^{36 \cdot r_p \cdot r_p/(r_e \cdot r_e)}\} \cdot c_L^2 \cdot r_e / m_p = 6{,}674234 \cdot 10^{-11}\ m^3\ kg^{-1}\ s^{-2} \quad \text{(G-F3)}$$

Result of Equation (G-F3) uses about 44% of the lower Tolerance Range of the Gravitational Constant G.

Conclusion

By application of the Physical Constants Light Velocity c_L, Electron Radius r_e and Fine Structure Constant α and of a relative simple, but harmonic Equation for a Large Number LN an Approximation for the Age of the Universe could be presented, which result lies far within the Tolerance Range.

If the values of the Physical Constants "Fine Structure Constant, Electron Radius, Light Velocity", which are used at the Formula (Age-Appr) for the Age of the Universe, haven't changed since the Big Bang, the following question arises: what meaning has it to the Formula (Age-Appr), because the Formula is only valid for a certain time period within the tolerance range of the Age of the Universe?

Referring this context an extract of the author's report [7] is repeated because of the time range analogy: *Please look again at the two Equations (RT_{Earth}) and (RT_{Moon})* [RT: Rotation Time] *with their inversive terms to each other! Consider that the result values are only valid during a certain earthly time period and that the relations were found in this period. If the development of the earth with the moon or mankind itself had changed just a little bit different, the result values never would have been possessed this correctness to the existing values, neither in the past nor in the future!* [see extract at page 2 of report [7]]

Furthermore some Large Numbers LN in dependence on the Proton Radius are presented for an exact calculation of the Gravitational Constant. One of these Large Numbers leads to Equations for the Gravitational Constant G with a similar term as used for the Equation for the Age of the Universe.

Please look again at the impressive used terms: $\mathbf{(4\pi/\alpha)^{4\pi}}$ and $\mathbf{(5\pi/\alpha)^{5\pi}}$

At the end the author takes the permission to present an Aphorism, which begins with a question:

Dear Reader, can you imagine the invisible note below this mathematical terms and the signature?

"Now it may possible for the mankind to see, that I am the Creator of the Universe.
Every Human Being has its free will to accept it or not."
[Signature] God

Used Data of Physical Constants:

Electron Charge e[3.7]:	$1{,}602\,176\,634 \cdot 10^{-19}$ C
Fine Structure Constant α[3.3]:	$7{,}297\,352\,5693(11) \cdot 10^{-3}$
Inverse of Fine Structure Constant $1/\alpha$[3.4]:	137,035 999 084(21)
Gravitational Constant G[3.8]:	$6{,}67430(15) \cdot 10^{-11}\ m^3\ kg^{-1}\ s^{-2}$
Light velocity c_L[3.1]:	299 792 458 m/s
Magnetic Field Constant μ_0[3.5]:	$1{,}256\,637\,062\,12(19) \cdot 10^{-6}$ kg m C^{-2}
Mass of Electron m_e[3.6]:	$9{,}109\,383\,7015(28) \cdot 10^{-31}$ kg
Mass of Proton m_p[5]:	$1{,}672\,621\,923\,69(51) \cdot 10^{-27}$ kg
Plancks Constant h[3.9]:	$6{,}626\,070\,15 \cdot 10^{-34}$ J s
Radius of Electron r_e[3.2]:	$2{,}817\,940\,3262(13) \cdot 10^{-15}$ m
Radius of Proton r_p[4]:	$0{,}84087(39) \cdot 10^{-15}$ m

The figures in the brackets behind the data descibe the uncertainty referring the last places of the given value[3].

Literature and wikipedia.de-Entries:

The data of the physical Constants are taken from the entries of Wikipedia Germany. The Physical Constants given in the corresponding entries refer mostly to CODATA 2018.
The reason of this choice can be read in the authors report[9] at section 8 (Page 13 and 14). For the calculation of the Universe Age by the Equation (Age-Appr) it takes a very neclegtable influence independent, if one uses the values of CODATA 2018 or a later CODATA-Version.

[1] Wikipedia.de-Entry “Large Number Hypothesis“; Status February 2025

[2] Wikipedia.de-Entry “Universum“; Status February 2025
2. Planck 2018 results. VI. Cosmological parameters. In: Astronomy & Astrophysics. Band 641. Planck Collaboration, 2020, S. A6, PDF Seiten 15, Tabelle 2: "Age/Gyr", letzte Spalte, doi:10.1051/0004-6361/201833910 (https://doi.org/10.1051/0004-6361%2F201833910), arxiv:1807.06209 (https://arxiv.org/abs/1807.06209), bibcode:2020A&A...641A...6P (https://ui.adsabs.harvard.edu/abs/2020A&A...641A...6P) (englisch)

[3] Wikipedia.de-Entry “Physikalische Konstante“; Status May 2024

[3.1] Light Velocity c_L:
12. CODATA Recommended Values. (https://physics.nist.gov/cgi-bin/cuu/Value?c) NIST, abgerufen am 3. Juni 2019 (englisch, Wert für die Lichtgeschwindigkeit).

[3.2] Electron Radius r_e:
45. CODATA Recommended Values. (https://physics.nist.gov/cgi-bin/cuu/Value?re) NIST, abgerufen am 3. Juni 2019 (englisch, Wert für den klassischen Elektronenradius).

[3.3] Fine Structure Constant α:
25. CODATA Recommended Values. (https://physics.nist.gov/cgi-bin/cuu/Value?alph) NIST, abgerufen am 20. April 2020 (englisch, Wert für die Feinstrukturkonstante)

[3.4] Inverse of Fine Structure Constant α^{-1}:
26. CODATA Recommended Values. (https://physics.nist.gov/cgi-bin/cuu/Value?alphinv) NIST, abgerufen am 20. April 2020 (englisch, Kehrwert der Feinstrukturkonstante)

[3.5] Magnetic Field Constant μ_0:
66. CODATA Recommended Values. (https://physics.nist.gov/cgi-bin/cuu/Value?gn) NIST, abgerufen am 21. März 2022 (englisch, Wert für die Normfallbeschleunigung).

[3.6] Electron Mass m_e:
41. CODATA Recommended Values. (https://physics.nist.gov/cgi-bin/cuu/Value?me) NIST, abgerufen am 3. Juni 2019 (englisch, Wert für die Elektronenmasse in Kilogramm).

[3.7] Electron Charge e:
13. CODATA Recommended Values. (https://physics.nist.gov/cgi-bin/cuu/Value?e) NIST, abgerufen am 3. Juni 2019 (englisch, Wert für die Elementarladung).

[3.8] Gravitational Constant G:
29. CODATA Recommended Values. (https://physics.nist.gov/cgi-bin/cuu/Value?bg) NIST, abgerufen am 3. Juni 2019 (englisch, Wert für die Gravitationskonstante).

[3.9] Plancks Constant h:
17. CODATA Recommended Values. (https://physics.nist.gov/cgi-bin/cuu/Value?h) NIST, abgerufen am 3. Juni 2019 (englisch, Wert für die Planck-Konstante in der Einheit Js).

[4] Muonic hydrogen and the proton radius puzzle; Randolf Pohl.
Published at arXiv: 1301.0905v2, doi: 10.1146/annurev-nucl-102212-170627
[The Proton Radius is listed at page 3 and page 58]

[5] Wikipedia.de-Entry “Proton“; Status March 2024
1. Die Angaben über die Teilcheneigenschaften (Infobox) sind, wenn nicht anders angegeben, entnommen aus: CODATA Recommended Values. (https://physics.nist.gov/cgi-bin/cuu/Category?view=html&Atomic+and+nuclear.x=114&Atomic+and+nuclear.y=16) National Institute of Standards and Technology, abgerufen am 21. Juli 2019.

[6] LAUFENDE KOPPLUNGSKONSTANTEN ZEIGEN DEN WEG ZUR WELTFORMEL DER NATURKONSTANTEN; Dr. Endre Kereszturi; 12.12.2010
[The Formula for the Gravitational Constant is listed at page 16 with Equation (19)]

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