# The neutron enigma

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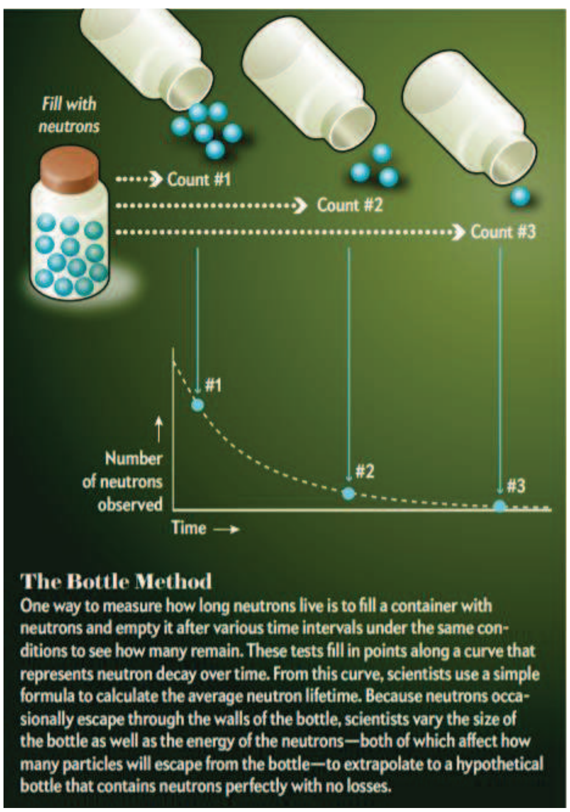
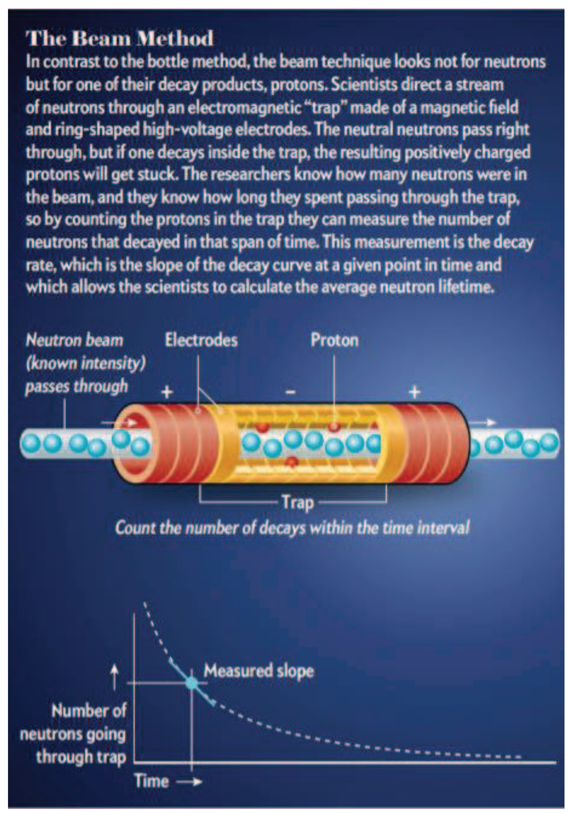
## Abstract

The lifetime of the neutron is still discussed very controversially, because two different measurement methods give two values, which differ from each other far beyond the standard deviations of the single measurements. In this work, two formulas with slightly modified initial parameters for calculating the lifetime of the neutron were established, each of which agrees with the measured values of the two measurement methods within the error limits.
The bases of the calculations suggest that the discrepancy in the measured values is not due to systematic errors in the measurement procedures, but rather that the β-electrons are in an excited state during the beam experiment, which alters the energy balance of the decay process and thus the lifetime of the neutron


## Introduction

The two very different methods for determining the average lifetime of neutrons are shown in detail in Figs. 1a u. b.




[1]Fig. 1a Bottle method 1b Beam method

[2]Bottle method: TN1 = 878.5 ±0.8 s
[3]Beam method: TN2 = 887.7 ±2.2 s

The results of the measurement series by A. Serebrov[2] et al. and those by E. Wietfeldt and Geoffrey L. Green[3] are listed above. These series of measurements were considered by us to have been carried out with particular care and the resulting measured values were therefore adopted as binding for this work. The discrepancy of about 9 s is clearly larger than the respective error limits allow. This unexpected and unsatisfactory result was confirmed by numerous other working groups, so that finally a systematic error in one of the two methods or an "exotic physics" with dark matter as decay product were considered. Despite a painstaking search, no systematic errors could be detected and also the evaluation of the energy distribution of the decay products did not give any hint for the formation of dark matter[5], so that the neutron lifetime puzzle must still be considered as completely unsolved.

**Calculations**

It should be briefly noted that in order to understand these calculations, it is of great advantage to know the "projection theory " [4] presented in an earlier paper on this forum.
This is based on a few minimum quantities, of which the quantities mentioned below are important for the further calculations.

- smallest distance: $s_{min} = \lambda_{CP} = 1.3214098\ 10^{-15}$ m
- smallest time unit: $t_{min} = s_{min}/c = 4.4077468\ 10^{-24}$ s ($c = s_{min}/ t_{min}$)
- smallest stable mass = proton mass: $m_P = 1.672621923\ 10^{-27}$ kg

The Plank's quantum of action h represents, as is well known, the smallest unit of action and, following the projection theory, is necessarily built up from the above-mentioned smallest units.
In the momentum-x-length-form the following results for

$$h = \frac{m_P s_{\min}{}^2}{t_{\min}} = m_P s_{\min} c = 6,6260701 \cdot 10^{-34}\,J$$

For the following calculations, however, the energy-x-time form is of importance, which we obtain by extending the fraction with $t_{min}$.

$$h = \frac{m_P s_{\min}{}^2 t_{\min}}{t_{\min}{}^2} = m_P c^2 t_{\min} = 6,6260701 \cdot 10^{-34}\,J$$

From the above minimum quantities, pixel numbers can be constructed analogously to digital photography.
The pixel number for the area resolution, i.e., the number of the smallest electronically resolved areas $F_{min}$ per sensor chip area $F_{Ch}$ is a very important parameter for the quality of a digital photograph.

$F_{pix} = F_{Ch}/F_{min}$ e.g. 10MPix

As the most important pixel number in the projection theory so far, the number of the smallest time-length areas per time-length unit area was introduced, which plays among other things a role in the calculation of the gravitational constant.

$N_{pix} = s_E t_E / s_{min}\, t_{min} = 1{,}716902\ 10^{38}$

For this work, the temporal resolution, i.e., the number of smallest time units per unit time $t_E$, is important.

$t_{pix} = t_E/t_{min} = 2{,}26873182\ 10^{23}$

Now we come to the actual problem. We have the particles Px and Py for which applies:

Px $\longrightarrow$ Py + $\Delta m_x c^2$ (e.g., x-rays).

Tx lifetime of the particle Px

$$T_x = \frac{h}{\Delta m_x c^2} = \frac{m_P c^2 t_{\min}}{\Delta m_x c^2} = x t_{\min}$$

The decisive factor in this calculation presented here is the ratio of the immanent energy of the Plank's quantum of action to the energy released during decay. We get a factor x related to the minimum time. To normalize this factor x to the unit time (seconds), we have to multiply by $t_{pix}$.

$$T_x = \frac{h}{\Delta m_x c^2} t_{pix} \left[s\right]$$

There is still the problem of the sign in the formation of Δm, since we can basically set the summands arbitrarily.

$\Delta m = m_1 - m_2$ or $\Delta m = m_2 - m_1$

In the first statement made above:

$m_1 > m_2 \rightarrow \quad +\Delta m$

$m_1 < m_2 \rightarrow \quad -\Delta m$

However, a negative Δm leads to a negative time in the calculation, which of course makes little sense. Therefore, we always insert the absolute value for Δm and the sign of the subtraction only indicates in which direction the decay reaction proceeds

$+\Delta m \longrightarrow$

$-\Delta m \longleftarrow$

$$T_x = \frac{m_P c^2 t_{\min}}{\left|\Delta m_x\right| c^2} t_{pix} \left[s\right]$$

Furthermore, it is certainly useful to consider the upper and lower limits of the above equation and normalize them if necessary.

$\Delta_m \longrightarrow 0 \qquad T_x \longrightarrow \infty \longrightarrow$ stable particle

The upper limit makes sense. A conversion from one particle to another without energy dissipation, does not occur. The original particle is stable.

$\Delta_m \longrightarrow \infty \qquad T_x \longrightarrow 0$

With this definition, it takes an infinite mass difference between the particles Px and Py to define Px as non-existent. This obviously contradicts physical observations.

We therefore fix:

$m_P \geq \Delta m$

and for

$\Delta_m = m_p \longrightarrow T_x = 0$

Consequently, we have to modify the equation above a little bit more

$$T_x = \frac{h}{|\Delta m_x| c^2} - 1 = \frac{m_P c^2 t_{\min}}{|\Delta m_x| c^2} t_{pix} - 1 [s]$$

As the later calculations revealed, we need one more factor, the dimension factor,

$$f_{D4} = \frac{1}{\sqrt{1 - \left(\frac{1}{4}\right)^2}}$$

which appeared for the first time at the derivation of the gravitational constant (see projection theory “The (Newtonian) gravitational constant") and enters there in reciprocal form into the calculation.

$$G = \frac{V_P \cdot c}{6 m_p \cdot s_E t_E} \sqrt{1 - \left(\tfrac{1}{4}\right)^2} \left[ \frac{m^3}{\mathrm{s}^2\, kg} \right]$$

This factor finally causes a reduction of the forces from four to the one dimension in which the measurement of our forces between two test bodies takes place. It can also be understood as a special case of the Lorentz factor from the SRT.
Interestingly, this factor enters into our calculations with the 6th power, which could not be derived so far. Since there are 6 space directions and the effect of the forces is determined usually only in one direction, a first assumption goes that this dimension factor enters multiplicatively per space direction into the formula. But this is only a first assumption, as already mentioned.

$$T_x = \left( \frac{h}{|\Delta m_x| c^2} t_{pix} - 1 \right) \left( \frac{1}{\sqrt{1 - \left(\frac{1}{4}\right)^2}} \right)^6$$

We now transfer the above equation to our fundamental problem, the neutron decay and obtain:

$$T_{N1} = \left( \frac{h}{(m_N - m_P) \cdot c^2} t_{pix} - 1 \right) \left( \frac{1}{\sqrt{1 - \left(\frac{1}{4}\right)^2}} \right)^6 = 879{,}24 [s]$$

The result itself is convincing and agrees with the measured value of Serebrov et al. within the limits of error.

[2]Bottle method measured: $T_{N1}$ = 878.5 ±0.8 s.

But how do the calculation bases change to correctly calculate the lifetime of the neutron in the beam method. Surprisingly, the solution was not very difficult to find. We only need the additional term $m_e/k_{Pe}{}^{½}$ at the energy differences in the denominator.

$$T_{N2} = \left( \frac{h}{\left| \left( m_N - m_P - \frac{m_e}{\sqrt{k_{Pe}}} \right) \right| \cdot c^2} t_{pix} - 1 \right) \left( \frac{1}{\sqrt{1-\left(\frac{1}{4}\right)^2}} \right)^6 = 887{,}43\left[s\right]$$

The result agrees excellently with the value determined by beam method.

[3]Beam method measured: $T_{N2}$ = 887.7 ±2.2 s

But how can the additional term introduced above be interpreted?
The ratio of proton to electron mass, $k_{pe}$, is a very important constant in projection theory, especially after it could be shown that it represents the physically relevant kernel of Sommerfeld's fine structure constant α.

$$k_{Pe} = \frac{m_P}{m_e}$$

$$\alpha = \frac{4\pi}{k_{Pe} f_{D42}{}^2}$$

($f_{D42}$ is a slightly modified $f_{D4}$, see Projection Theory "The dimension-factor $f_{D42}$" [4].

Solving the last equation for $1/k_{Pe}$ and taking the root we get:

$$\sqrt{\frac{1}{k_{Pe}}} = \sqrt{\alpha}\sqrt{\frac{f_{D42}{}^2}{4\pi}} = \frac{\sqrt{\alpha}}{2}\frac{f_{D42}}{\sqrt{\pi}}$$

We substitute the right-hand expression into the above equation for the calculation of $T_{N2}$, separate the newly introduced term, and obtain

$$T_{N2} = \left( \frac{h}{\left| \left( (m_N - m_P)c^2 \right) - \frac{\sqrt{\alpha}}{2} m_e c^2 \frac{f_{D42}}{\sqrt{\pi}} \right|} t_{pix} - 1 \right) \left( \frac{1}{\sqrt{1-\left(\frac{1}{4}\right)^2}} \right)^6 \left[s\right]$$

Let us now consider the formulas for the energy levels of the main lines of hydrogen (see projection theory: "The Bohr atomic model under a new aspect")

$$E_{ges(n_i)} = -\frac{1}{n_i^2}\left[\frac{\alpha^2}{2} m_e c^2\right][J]$$

especially for the case $n_i = 1$

$$E_{ges} = -\left[\frac{\alpha^2}{2} m_e c^2\right][J] \text{ (Rydberg constant)}$$

the formal agreement with the red marked part of the above equation becomes immediately clear, i.e., in the beam experiment, in contrast to the bottle experiment, the emitted electron is in an excited state, the essential difference to the Bohr excitation levels being in the power of α. We are here at a much higher energy level, namely in the range of the characteristic X-ray radiation and not as in the case of the energy transitions of the shell electrons in the range of the visible electromagnetic radiation.

**Summery**

It must be admitted at this point, however, that the equations were not completely derived, consequently are to be classified as semi-empirical.
In particular, it is unclear why the factor $f_{D4}$ is in the 6th power. This could have to do, as already noted above, with the 6 spatial directions. Furthermore, it is unclear why, in contrast to the calculation of the max. kinetic energy of the β-electrons, the rest energy of the electron is missing in the energy balance when calculating the average lifetime.
The attraction of the equations presented above is that they give excellent results for the lifetime of the neutron and, above all, that they show a concrete, experimentally verifiable cause for the different decay times depending on the particular experiment. It would now be an urgent task for experimental physicists - if it is at all technically feasible - to verify whether and, if so, to what extent the maximum kinetic energy of the β-electrons in the beam experiments is higher than that of the electrons in the bottle experiment.

Should this value

= 11.925 keV

one could consider the calculations presented here as largely verified and the "neutron enigma" as solved, despite the fact that the derivation of the equations is not yet complete.

Unfortunately, these simple lifetime calculations cannot be applied to the decay series of complex radioactive atomic nuclei. Here, as in many complex chemical reactions, the kinetics inhibited by high-energy intermediates obviously plays a greater role than the thermodynamic data.

*Literature*

[1]*Scientific American, April 2016, S. 37 - 41*

[2]*Measurement of the Neutron Lifetime Using a Gravitational Trap and a Low Temperature Fomblin Coating. A. Serebrov et al. in Physics Letters B, Vol. 605, Nos. 1–2, pages 72–78; January 6, 2005.*

[3]*The Neutron Lifetime. Fred E.Wietfeldtand, Geoffrey L. Greene in Reviews of Modern Physics, Vol. 83, No. 4, Article No. 1173; October–December 2011.*

[4]*The Projection Theory: an Approach to the Theory of Everything*
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[5]Florian Aigner, Das Rätsel der zerfallenden Neutronen
Mitteilungen der TU Wien vom 10. Juni 2019