NATURAL UNITS: THE MUON LIFETIME

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References: Amitabha Lahiri & P. B. Pal, *A First Book of Quantum Field Theory*, Second Edition (Alpha Science International, 2004) - Chapter 1, Problem 1.8.

In natural units $\hbar=1$ and $c=1$ which results in every physical quantity being expressed in units of mass. As an example, the muon lifetime τ is given by

$$\tau^{-1}=\frac{G_F^2 m^5}{192\pi^3} \tag{1}$$

where m is the muon mass which is 106 MeV and G_F is the Fermi coupling constant, which comes out of the quantum field theory of the electroweak interaction (more on this [much] later, hopefully). Since time has natural units of inverse mass M^{-1}, the units of G_F must be M^{-2} to make the units balance out.

To convert this formula into SI units, we need to insert factors of $\hbar$ and c so that the LHS has units of s^{-1}. Since the units are currently M^1 where mass is expressed in MeV, which is an energy unit, and the units of $\hbar$ are those of action, which is $(\text{energy})\times(\text{time})$, we can divide by $\hbar$ to get overall units of $(\text{time})^{-1}$. Thus

$$\tau^{-1}=\frac{G_F^2 m^5}{192\pi^3\hbar} \tag{2}$$

Given that $G_F=1.166\times10^{-11}\ \mathrm{MeV}^{-2}$ and $\hbar=6.58\times10^{-22}$ MeV s, we get

$$\tau^{-1} = 4.645\times10^{5}\ \mathrm{s}^{-1} \tag{3}$$

$$\tau = 2.15\times10^{-6}\ \mathrm{s} \tag{4}$$

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