Natural Nonlinear Quantum Units and Human Artificial Linear System of Units

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Diving into the nonlinear massive range of nuclear physics, the quark model already indicates that the linearized massless length scales break down. Although we are often confronted with nonlinear and relativistic dynamics, we obtain our fundamental values with the classical linear system of units SI by linear extrapolation. Ignoring the correspondent nonlinear relations while extrapolating to the Planck scale $h = c = \mu = 1$ based on linear massless relations leads to pseudo-scales equivalent to geometrized mass units. This paper shows that one of the fundamental dimensions length, time, mass becomes redundant approaching the Planck scale. The hidden information can be assigned to a geometrized natural quantum mass unit μ part of the Planck constant h. In other words: c, h, and μ are interrelated.

Introduction. A nice trialogue on the number of fundamental constants can be found in [1]. The message is that there is at present no common rule to decide how many independent constants exist. The discussion somehow shows a lack of orientation and coherence in fundamental physical questions. The motivation to approach this subject is usually to identify dimensionless constants and fundamental scales that can be converted to dimensionless Planck units. 1844, when a young Scottish engineer named John Scott Russell investigated the nature of water waves, nonlinear physics was the exception, nowadays linear physics is the exception. But why should we approach the fundamentals of nonlinear relativistic dynamics with a classical linear system of units obtained and therefore only valid in the low-energy limit? Probably for engineering purposes. Nevertheless, modern "Planck scale physics" relies on constants extrapolated from linear scales. Applying linear rules to nonlinear systems usually generates pseudo-scales and -predictions. This argument could vindicate fundamental high-energy scales that emerge by combining fundamental constants obtained with the linear standard prescribed by the system of units (SI). In a relativistic dynamics the measures of length, time, and mass are not decoupled or linear independent. A correct application of basic quantum and relativistic laws should allow to recover the real natural nonlinear quantum units out of the linear human artificial SI.

Quantum dynamics. The number of independent constants cannot be arbitrary and is probably reduced by combining nonlinear and/or relativistic constraints. This can be shown by regarding the energy-momentum relation of a massive particle with rest mass μ and momentum p given by

$$E^2 = p^2c^2 + \mu^2c^4, \tag{1}$$

where $E(p = 0) = E_\mu = \mu c^2$. After an elastic Compton collision the particle(s) initially at rest will gain kinetic energy $E - \mu c^2$ linearly related to the photon momentum difference $\triangle p$

$$E - \mu c^2 = \triangle pc\,. \tag{2}$$

The Planck constant provides with 1-dimensional 180 degree backscattering a Compton wavelength for a particle initially at rest

$$\lambda_\mu = \frac{h}{c\mu}. \tag{3}$$

In the standard description we have the 3 natural dimensions length, time, and mass that can be used to measure the 7 parameter $E, p, c, \mu, \lambda_\mu, h, \triangle p$. As usually, h, c, μ can be taken as constants, one variable degree of freedom is left and can be assigned to p, E, or $\triangle p/p$. A variable velocity v can also be introduced related to a particle wavelength λ via

$$p = vE/c^2 = h/\lambda, \tag{4}$$

the de Broglie relation. Eq.(1) - eq.(4) can be called representative for low-dimensional quantum physics. eq.(1) can be combined with eq.(2) to

$$\frac{(\triangle p)^2}{p^2} = \frac{E - \mu c^2}{E + \mu c^2}\,, \tag{5}$$

and shows that $\triangle p \leq p$.

Defining linear geometric units while working with natural quantum mass units. Assuming idealized linear relations, one degree of freedom allows to establish a system of units (of type SI) by defining a unit velocity reference $v = u = 1\text{m/s}$. Assuming an idealized decoupling of energy and dynamics while operating in the linear range $0 < u \ll c$, unit energy $E(v = u) = E_u$, and $E_\mu = \mu c^2$ are related by

$$\frac{E_u - E_\mu}{E_\mu} \approx \frac{u^2}{2c^2} = \frac{1}{2\Xi^2}, \quad \Xi = 299792458\,, \tag{6}$$

(in SI take n particles with $n\mu = 1\text{kg}$, $E_u \to 1\text{J} = 1\text{kg m}^2/\text{s}^2$). In a quantum system $E_\mu = \mu c^2$ can be a natural baryon-type quantum mass unit that can't be arbitrarily divided. Ignoring mass defects from nuclear and electromagnetic coupling, any arbitrary human artificial mass unit $m = n\mu$ contains a number n of natural quantum mass units, where n acts only as a discrete linear extension of eq.(1) - eq.(6). Simulating the SI-conditions of linear low-energy physics we proceed with an elastic collision of a photon with SI unit wavelength $\lambda_u = 1\text{m}$ and a proposed natural quantum mass u. The bouncing photon transfers twice it's total momentum $2\triangle p = 2(E_u - E_\mu)/c = 2h/\lambda_u$ according to eq.(6) to the unit mass (1kg in SI). We find for all n

$$2E_\mu \lambda_\mu = (E_u - E_\mu)\lambda_u, \quad \lambda_\mu = \lambda_u/\Xi^2 \approx 1.1 \cdot 10^{-17}\text{m}\,. \tag{7}$$

Note, that we have coupled two different types of dispersion relations: a massive nonlinear in eq.(1) $E(p)$ and a massless linear $E(\triangle p)$ in eq.(2). The linear relation can be handled by a simple one point linear calibration with a unit value obtaining all other values with linear inter- or extrapolation. But not the non-linear relativistic dispersion relation. If we apply a linear calibration to a nonlinear behavior we can almost be sure that we will obtain pseudo-scales by the linear extrapolation into the highly nonlinear range $v \approx c$. Although invariant, the Planck quantum eq.(3) can be assigned to idealized linear low-energy SI-conditions with photon wavelength $\triangle p/h \gg \lambda_\mu$. To get more understanding about the consequences of the linear SI-technique we must realize that

- we get pseudo-values from linear extrapolation,
- we can reinterpret those pseudo-values revealing hidden information.

The counter-intuitive strategy behind my proposals is to reveal the hidden relativistic and quantum aspects (that are not part of the SI-system):

- Near local SI reference points (the units) the measurement values are not linearly extrapolated. Operating with λ_u and u in eq.(6) and eq.(7) is a trick to eliminate those human artificial constants hidden in h, E_u, and E_μ and to escape the linear system.
- It is the quantum nature that the photon energy or wavelength (see i.e. photoelectric effect) is independent of the number of colliding quanta and n. Having a geometrized natural quantum mass units hidden in the human artificial mass unit the system is over–determined. Consequently, setting $h = c = \mu = 1$ can kill hidden dimensionless constants like n or Ξ. Ignoring n and Ξ can generate very small virtual scales compared to the "natural" Fermi scale.
- The mass unit $\mu > 0$ is given by the quantum nature $h > 0$, initiated by $c < \infty$, and defined with respect to the classical scale $0 < u \ll c$.

Discussion and conclusion. The fundamental dimensions length, time, mass are not linearly independent, a direct consequence of the massive relativistic dispersion relation eq.(1). From SR we already know that lengths depend on relative velocities. Knowing that the length in eq.(7) is the SI-generated geometrization of the natural mass unit μ, the traditional approach with three constants can now be reduced to two constants, i.e. to one length and one time unit connected to the natural mass unit μ. Clearly, the human artificial SI references $\lambda_u = 1$m and $u = 1$m/s can not have any fundamental physical meaning at all. It took several years for the community to realize that there was a hidden relation between mass and energy $E_\mu = \mu c^2$ with a proportionality constant given by the SI-system.

Not necessary to obtain the results but supporting the purpose and necessity of this paper: including another dimensionless quantum particle-wave coupling constant $q^{-2} = 12\pi^2$ that shifts the basic energy scale with $\mu \to q^2\mu$ [3], eq.(7) provides with eq.(3) for the basic natural mass quantum realized in SI units

$$\mu = \frac{\hbar}{c}\frac{\Xi^2}{6\pi\text{m}} = \frac{1\text{kg}}{n} \approx 1.67724... \cdot 10^{-27}\text{kg}\,, \tag{8}$$

that is 1.001382 times the neutron and 1.002762 times the proton mass [3, 4]. Setting $h = c = 1$ provides for $\mu = q^{-2}$ in Planck units.

We should remember that we connect in the Compton relation two different dispersion relations: and nonlinear massive eq.(1) and a linear massless scaling eq.(2). Using a system adjusted to the linear low-energy range this can generate virtual length scales when extrapolating to the high-energy massive range. Length scales obtained with massless photons and correspondent linear wave mechanics are real existing lengths. This class provides for a good estimation of the correct atomic dimensions, correspondent wavelengths, and Bohr-Sommerfeld-Dirac parameter. Diving into the nonlinear massive range of nuclear physics, the quark model already indicates that the linear massless length scales break down.

[1] M.J. Duff, L.B. Okun, G. Veneziano, JHEP 0203:023,2002; physics/0110060.

[2] B. Binder, *The Planck Mass Unit Hidden in the Planck Action Quantum* (2003); PITT-PHIL-SCI00000962.

[3] B. Binder, *Bosonization and Iterative Relations Beyond Field Theories* (2002); PITT-PHIL-SCI00000944.

[4] B. Binder, *With Iterative and Bosonized Coupling towards Fundamental Particle Properties*; corrected version; PITT-PHIL-SCI00000957.