Vacuum Potentials for the Two Only Permanent Free Particles, Proton and Electron. Pair Productions

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Abstract.

The two only species of isolatable, smallest, or unit charges $+e$ and $-e$ present in nature interact with the universal vacuum in a polarisable dielectric representation through two uniquely defined vacuum potential functions. All of the non-composite subatomic particles containing one-unit charges, $+e$ or $-e$, are therefore formed in terms of the IED model of the respective charges, of zero rest masses, oscillating in either of the two unique vacuum potential fields, together with the radiation waves of their own charges. In this paper we give a first principles treatment of the dynamics of charge in a dielectric vacuum, based on which, combined with solutions for the radiation waves obtained previously, we subsequently derive the vacuum potential function for a given charge $q$, which we show to be quadratic and consist each of quantised potential levels, giving therefore rise to quantised characteristic oscillation frequencies of the charge and accordingly quantised, sharply-defined masses of the IED particles. By further combining with relevant experimental properties as input information, we determine the IED particles built from the charges $+e$, $-e$ at their first excited states in the respective vacuum potential wells to be the proton and the electron, the observationally two only stable (permanently lived) and "free" particles containing one-unit charges. Their antiparticles as produced in pair productions can be accordingly determined. The characteristics of all of the other more energetic single-charged non-composite subatomic particles can also be recognised. We finally discuss the energy condition for pair production, which requires two successive energy supplies to (1) first disintegrate the bound pair of vaculeon charges $+e$, $-e$ composing a vacuuon of the vacuum and (2) impart masses to the disintegrated charges.

1. Introduction

Up to the present several hundreds of isolatable subatomic particles along with their antiparticles have been discovered, of these the very energetic and (or) short lived ones existing only in high energy accelerators and cosmic ray radiation[1]. Of these observational particles, the proton (E Rutherford, 1919[1]) and the electron (J J Thomson, 1897[1]) are the only two particle species containing one-unit charges which are stable, or permanently lived, and "free" (i.e. available for building the usual materials with no need of "extraction") in the vacuum; they are the building constituents of all atoms. While conceding such "privileged" status only to these two particular opposite charged particles, nature differentiates the two by unequal masses, with the proton being about 1836 times heavier than the electron. Nature differentiates their opposite charged antiparticles, antiproton and positron, with a similar mass asymmetry, and nevertheless appears to admit both with a similar permanent lifetime expectation. Although, if pair productions are the only sources of their creations in the real physical world, the antiprotons would appear to be prominently missing, and the positrons appear to be similarly missing, or "hidden" in the
vacuum. The fundamental reason for this selective, asymmetric preference of nature for our physical world is up to the present not explained.

This selective, asymmetric characteristic of the particle system has been one essential constraint imposed from the beginning upon the construction of an *internally electrodynamic* (IED) particle model and *vacuuonic vacuum structure*, which the author carried out in recent work [2]-[16] based on overall relevant experimental observations as input information. According to the construction, briefly, a single-charged matter particle like the electron, proton, etc., is composed of (i) a point-like charge \( q \) (as source) of a zero rest mass but of an oscillation of characteristic frequency \( \Omega \) and (ii) the electromagnetic waves \( \mathbf{E}, \mathbf{B} \) generated by the oscillating charge. And the vacuum is filled of electrically neutral but polarisable building entities, vacuuons (to be detailed in Sec. 4), separated at a mean distance \( b_v \); this vacuum is an electrically polarisable dielectric medium. Representations of the IED particle based mainly on solutions for the electromagnetic wave component have been the subjects of previous investigations [2]-[15], which have yielded predictions of a range of the long established basic properties and relations of particles under corresponding conditions.

In this paper, in terms of first principles solutions for the charge to be obtained first (Sec. 2) and for the electromagnetic wave component of an IED particle obtained previously [2]-[6] we formally derive in Sec. 2 the vacuum potential function for a specified charge \( q \). Further combining with relevant experimental properties for particles as input information, we parameterise the vacuum potential functions for the two unit charges \( +e, -e \), and determine accordingly the dynamical states of the two only stable, "free" particles formed therein out of the two respective charges, the proton and electron, and their antiparticles; and we elucidate the characteristics of the remaining, more energetic subatomic particles containing one-unit charges (Sec. 3). Finally, we establish the vacuuonic potentials and elucidate the energy condition for pair production (Sec. 4).

2. Vacuum potential functions of charges \( +e, -e \)

We consider a substantial vacuum constituted of vacuuons densely packed relative to one another[2, 9, 10] as represented in a three-dimensional flat euclidean space \( (\mathbb{R}^3) \), spanned here by three Cartesian coordinates \( X, Y, Z \) fixed in the vacuum. Let a charge \( q \) of zero rest mass be located at \( \mathbf{R}_q( X_q, Y_q, Z_q ) \) in an interstice \( i \) of the vacuuons. Suppose that the charge had been continuously driven for a finite duration \( -\Delta t' \) in past time, up to the present time \( t = 0 \), by an alternating force \( \mathbf{F}_{0i} \) of a characteristic frequency \( \Omega \) and, in addition, a unidirectional force \( \mathbf{F}_{i0} \) in the \( X \) direction here, into possession of a total Hamiltonian \( \varepsilon_q \). Suppose that the charge is for the present prevented from radiating; and from time \( t = 0 \), the initial applied force \( \mathbf{F}_{app,0}( = \mathbf{F}_{i0} + \mathbf{F}_{0i} ) \) has ceased action. Therefore, from \( t = 0 \), the charge will tend to move spontaneously, say making a displacement \( \mathbf{u}_q(t) = \mathbf{R}_q(t) - \mathbf{R}_i \) at time \( t \) from its equilibrium position, \( \mathbf{R}_i \). A (spontaneous) inertial force \( \mathbf{F}_{ine}(\equiv \mathbf{F}_{app,0}) \) is therefore according to Newton’s law of inertia associated with \( d^2 \mathbf{u}_q = \frac{d^2 \mathbf{u}_q}{dt^2} \), as \( \mathbf{F}_{ine} = m_q \frac{d^2 \mathbf{u}_q}{dt^2} \), where \( m_q \) is a proportionality constant, or the "(dynamical) inertial mass" of \( q \).

In the vacuuonic vacuum, the motion of the charge \( q \) is resisted. This is as a consequence that the vacuuons become polarised about \( q \) and builds with \( q \) an interaction potential, \( V_{vq}(\mathbf{R}_q) = V_{vq0} + \sum_n \frac{1}{n!} \nabla^n V_{vq}(\mathbf{R}_i) \mathbf{u}_q^n \), where \( V_{vq0} = V_{vq}(\mathbf{R}_i) \) is the minimum value of \( V_{vq} \); \( V_{vq} \) is the superimposed result of the electrostatic interactions \( V_{vq} \) of \( q \) with all of individual polarised vacuuons \( j \) up to an intermediate range about \( q \), \( V_{vq}(\mathbf{R}_q) = \sum_j V_{vqj} \) (see further Sec. 4 and Appendix A). The corresponding restoring force is \( \mathbf{F}_{res} = -\nabla V_{vq}(\mathbf{R}_q) - 0 \). On equal footing with the fact that radiation fields of an accelerated charge, as the \( q \) here, ordinarily obey the linear Maxwell’s equations and are accordingly linear, \( V_{vq}(\mathbf{R}_q) \) therefore follows to be generally relatively small. So, as it suffices, retaining the first two leading terms only, with odd terms vanishing for an isotropic vacuum, the \( V_{vq}(\mathbf{R}_q) \) and \( \mathbf{F}_{res} \) are thus given as, assuming
for the illustration below along the Z direction and hence $\mathcal{U}_q(= z) = Z_q - Z_i$,

$$V_{Vq}(\mathcal{U}_q) = V_{Vq0} + \frac{1}{2}\beta_q \mathcal{U}_q^2, \quad \beta_q = \nabla^2 V_{Vq}, \quad F_{res} = -\beta_q \mathcal{U}_q. \quad (1)$$

The charge q is by construction point like relative to its radiation waves, but is extensive across each interstice of the vacuums of a size $\sim b_v$. The latter extensive feature is requisite in order to conform to the overall basic experimental properties of charge, including spin as represented in [2] and the quantisation of energy to be elucidated below; an extensive q will be mainly involved in this paper. Concretely, q is a spinning liquid-like entity, or whirlpool, extending across the interstice region $(-b_y, b_y)$ of vacuums [2, 16]; $b_v \approx 1 \times 10^{-18}$ m by a crude estimate based on experiment [17]. Let this minute extensive spinning q be described by a (normalised) probability density $\rho_q(z, t) = |\psi_q(z, t)|^2$ along the z direction here. $\rho_q(z, t)$ is associated with a density flow in the z direction here, $j_q = \psi_q \rho_q$ that is complex for the $\psi_q$ being complex, $v_q$ being the flow velocity. Alternatively, $j_q$ is according to Appendix B a diffusion current $j_q = -D_q(\nabla \psi_q^* \psi_q - \psi_q^* \nabla \psi_q)$, where $D_q = \frac{i\hbar}{2\mathcal{M}_q}$ is an imaginary diffusion constant.

We are here mainly interested in the formation of stable particles (or particle states) from the charge and therefore the stationary states of the charge. To attain such states, the minute extensive charge must necessarily move as a whole as a rigid object. This will be ensured if $\rho_q$ fulfils the continuity equation,

$$\partial_t \rho_q + \nabla(\rho_q v_q) = 0 \quad \text{or} \quad \partial_t \rho_q - D_q(\nabla^2 \psi_q^* \psi_q - \psi_q^* \nabla^2 \psi_q) = 0. \quad (2)$$

Under the condition (2), and generally also in the presence of an external (total) force $F_{ext}$, the equation of motion of the minute charge from time $t = 0$ is given according to Newton’s second law as $F_{inc} - F_{res} + F_{ext} = 0$, or,

$$\partial_t^2 \mathcal{U}_q + \omega^2 \mathcal{U}_q + F_{ext}/\mathcal{M}_q = 0, \quad \omega = \gamma \Omega, \quad \Omega = \sqrt{\beta_q/\mathcal{M}_q}, \quad (3)$$

where $\gamma = 1/\sqrt{1 - v^2/c^2}$ given by the solution for the electromagnetic waves radiated by the charge [2],[4].

In an ordinary environment there always present certain random radiation fields, which can statistically act (a) a torque $F_{ran} \times \mathbf{d}$ on the oscillating-charge dipole, and (b) a linear force $F_{ran}$ on the charge’s mass centre. Due to (a), $\mathcal{U}_q$ may alter in orientation at every brief yet finite time interval, and will explore all orientations over long time. Due to (b), the charge may be promoted to hop over an energy barrier $\Delta_q$ to a neighbouring site, randomly in any possible directions. An applied unidirectional force ($F_u$), here the $F_{0d}$ acted up to initial time $t = 0$ in the X direction earlier, will ordinate the hopping in a fixed X direction at velocity $v = \frac{1}{\epsilon} \sum N \frac{X_{next} - X_i}{\delta t_i}$, $\delta t_i$ being the dwelling time at site i. The $F_{ran}$ above, the $F_{app}$ earlier, and the $F_{rad}$ of Appendix C later are all contributions to $F_{ext}$.

We below consider first the pure dynamics of the charge about the fixed site $R_i$, and thus set $F_{ext} = 0$. Equation (3), to consider first, has a general complex harmonic displacement solution

$$\mathcal{U}_q^c(t) = A_q \theta_q(t), \quad \theta_q(t) = e^{(\omega t + \alpha_0)}; \quad \mathcal{U}_q(t) = \text{Re}[\mathcal{U}_q^c(t)]; \quad (4)$$

i.e., in the absence of external perturbation, the minute charge as a whole executes a harmonic oscillation of real displacement $\mathcal{U}_q$ in the quadratic potential well $V_{Vq}$ given in (1). The corresponding kinetic and elastic potential energies are thus $\varepsilon_{pq}(t) = \frac{1}{2} \mathcal{M}_q \mathcal{U}_q^2(t)$ and $\gamma_q(t) = V_{Vq}(\mathcal{U}_q(t)) - V_{Vq0} = \frac{1}{2} \gamma_q \mathcal{U}_q^2(t)$; and the total mechanical energy, or total Hamiltonian, is

$$\varepsilon_q(t) = \varepsilon_{pq}(t) + \gamma_q(t) = \varepsilon_q |\theta_q(t)|^2 = \varepsilon_q, \quad \varepsilon_q = \frac{1}{2} \mathcal{M}_q \Omega^2 \theta_q^2. \quad (5)$$
where \( |\theta_q(t)|^2 = 1 \); (5) defines a stationary state for the harmonically oscillating charge.

The constraining equation (2) decomposes into two conjugate second order differential equations for \( \psi_q \) and \( \psi_q^* \), that are mathematically equivalent to the Schrödinger equations for a harmonic oscillator. The solution for \( \psi_q \) (and similarly \( \psi^* \)) follows to be the standard hermit polynomial (e.g. [18]). And the energy solution, restricting for simplicity here to the excitations which create matter particles only, consists of quantised levels,

\[ \varepsilon_{qn} = n\hbar\omega, \quad n = 1, 2, \ldots \]

where a mathematically permitted term \( \frac{1}{2}\hbar\omega \) is not physical and thus dropped based on a comparison with the empirical Plank energy equation for radiation. (6) is a prediction of the Planck energy equation for the electromagnetic radiation associated with the \( \varepsilon_q \) here, and hence the mass \( m \) of the resulting IED particle to be specified below.

The charge in oscillatory motion normally will generate electromagnetic waves, gradually and thus continuously so as for the total system to manifest wave phenomena. The oscillating charge and its radiation fields together make up our IED particle. If the charge is let emit radiation only and (re)absorb none, after a time \( t_\phi \) its entire \( \varepsilon_q \) will thus have been converted to the total energy \( \varepsilon'' = (\sqrt{\varepsilon''^2 + \varepsilon''^1}) = \varepsilon_q \) of electromagnetic waves, consisting of two Doppler-effected opposite travelling components \( E^\dagger, E^\dagger \), of total \( E = E^\dagger + E^\dagger \) along a wave path, which extends as a wave train of a mean total length \( L_c. \) \( \varepsilon'' \) is given according to electromagnetic theory as \( \varepsilon'' = L_c c_0 \frac{\gamma}{c} |E|^2. \) Alternatively, from the perspective that they have a mean linear momentum \( p'' = \varepsilon''/c = \hbar k, \) with \( k = \omega/c, \) the electromagnetic waves are as if a rigid wave train travelling rectilinearly at the speed of light \( c \) here in an elastic vacuum. The same \( \varepsilon'' \) is thus now given [2, 4, 6] as the kinetic energy, \( \varepsilon_k = \frac{1}{2}m''c^2, \) of the wave train plus an elastic potential energy equal to \( \varepsilon_k, \) whence \( \varepsilon'' = 2\varepsilon_k = m''c^2, \) where \( m'' \) is the relativistic mass of the wave train and, equivalently (see e.g. [4]), the mass of the IED particle.

The \( \varepsilon'' \) above and the Newtonian result \( \varepsilon_q \) of (5), being equal to \( \varepsilon_{qn} \) each, follow therefore to be each quantised, in the inevitable way as

\[ \varepsilon'' \rightarrow \varepsilon_n = L_c c_0 E_n = m_n c^2, \quad \text{with } E'' \rightarrow E_n = \sqrt{n}E_1, \quad m'' \rightarrow m_n = nm, \]

\[ \varepsilon_q \rightarrow \varepsilon_{qn}^{\text{newt}} = \frac{1}{2} \gamma \beta_q \omega_{qn}^2, \quad \text{with } \omega_q \rightarrow \omega_{qn} = \sqrt{n}\omega_q^1, \]

and \( \beta_q = m_q\Omega^2 \) as given by (3c). From the equalities \( \varepsilon_n = \varepsilon_{qn}^{\text{newt}} = \varepsilon_{qn}, \) we obtain

\[ \omega = \frac{m c^2}{\hbar}, \quad \omega_q^1 = \left( \frac{2Mc^2}{\beta_q} \right)^{1/2}, \quad \text{or } \beta_q = \frac{2Mc^2}{\omega_q^1}, \quad m_q = \frac{2Mc^2}{\Omega^2\omega_q^1}, \]

where \( m \equiv m_1 = \gamma M \) is the relativistic mass and \( M = \lim_{v \rightarrow c^-} a_0 m \) the rest mass of the IED particle formed of the charge \( q \) at the energy level \( n = 1 \) of excited state.

Any massive materials in ordinary conditions in the surrounding will serve as non "absorbing" reflection walls to the wave of the energy quanta \( n \times \hbar \omega \) which can only be annihilated through pair processes. So from the nearest such walls the waves will be reflected back to the charge, be re-absorbed by it and then re-emitted, continuously and repeatedly. The total energy \( \varepsilon_{tn} \) of the IED particle is at any time carried a fraction \( a_1 \) by the charge and a fraction \( a_2 \) by the radiation wave, with \( 0 \leq a_1, a_2 \leq 1, \) \( a_1 + a_2 = 1. \) So \( \varepsilon_{tn} = a_1\varepsilon_{qn} + a_2\varepsilon_n; \) \( \varepsilon_{tn} \) is quantised. Accordingly, the actual potential of the charge is at any time a fraction \( a_1 \) of the total \( V_{qn}, \) \( a_1 V_{qn}; \) and this, as one will readily obtain by combining with the solution of Appendix C[16], is as a result that \( \omega_q^1 \) is scaled by \( \sqrt{a_1} \) to \( \sqrt{a_1}\omega_q^1. \) For the charge dynamics in connection to vacuum potential as the major concern below, we shall for simplicity return to the extreme situation of \( a_1 = 1, a_2 = 0. \)
With $\mathcal{A}_q \rightarrow \mathcal{A}_{qn}$, we have $\mathcal{U}_q \rightarrow \mathcal{U}_{qn} = \sqrt{n} \mathcal{A}_q \text{Re}[\theta_q]$, or $\mathcal{U}_{qn} = z_n = \sqrt{n} z$, $\zeta_n = z_n/b_v = \sqrt{n} \zeta$. Placing this $\mathcal{U}_{qn}$ in (1a), we obtain the quantised vacuum potential of charge $q$

$$V_{vqn}(z) = V_{vq0} + \frac{1}{2} \beta_q n z^2 = V_{vq0} + \frac{1}{2} \beta_q' n \zeta^2 \quad (|z| < b_v/2) \quad (10)$$

where $\beta_q' = b_v^2 \beta_q$. The $\beta_q$ and $V_{vq0}$ are fixed for a fixed $q$ value and the universal dielectric vacuum, if we disregard possible effects on the local instantaneous vacuum configurations from the variant sizes and frequencies $\omega$ of the charge. $V_{vqn}$ thus is an apparently uniquely defined function for a specified $q$. The two only isolatable, smallest or unit charges $+e$ and $-e$ present in nature therefore are associated with two unique vacuum potential functions.

3. Parameterisation of potential functions. Vacuum potentials for $p, e, \bar{p}, \bar{e}$

At the present we lack adequate input data, the vacuuon polarisability especially (see Appendix A), for an ab initio evaluation of $V_{vq}$. Instead, we shall below determine the parameters $\beta_q, V_{vq0}$ of the $V_{vq}$ function for charges $+e, -e$ based on experimental properties for particles, specifically the two most common particles proton ($p$) and electron ($e$) mainly. The parameterised potentials will in the end be characteristically justified by comparison with the direct electromagnetic interaction functions for an external $q$ and individual vacuuon given in Appendix A based on an assumed polarisability.

Observationally (e.g. [1]), the $p, e$ are (I) of sharply-defined constant rest masses $M_p, M_e$, (II) of the smallest masses (i.e. the $M_p, M_e$) among the particles which contain each one-unit $+e$ or $-e$ and also possess the properties (III)-(IV) below, (III) stable (i.e. of infinite lifetimes), and (IV) free in the vacuum in the sense that they are available for building the materials in our physical world with no need of extra energy for extraction. The oscillating charges $+e, -e$ composing the corresponding two IED particles are therefore required to be (i) stationary, i.e. being at one of the energy levels $n = 1, 2, \ldots$ following (6), (ii) factually at level $n = 1$ in accordance to property (II), (iii) of infinite lifetimes, and (iv) free in the vacuum. (iii) is to be justified and (iv) to be positioned by positioning of the level $n = 1$ below.

It follows from Appendix C that the time required for the (quasi) harmonically oscillating charge $q$ at the initial state $n = 1$ to have emitted its entire one energy quantum $\varepsilon_{q1} - \varepsilon_{q0}$, and transformed to the final state $n = 0$, is given after (C.3) as

$$t_{q1.0} = \infty. \quad (11)$$

By the usual quantum mechanical principle a transfer of only a fraction of a quantum $\hbar \omega$ from one charge $q$ to another charge $q'$ in their quantum states is forbidden, therefore a transition of charge $q$ from level $n = 1$ to $0$ within a finite time is improbable; this verifies the (iii) above. This restriction however does not apply if $q$ is in an asymmetric potential field, e.g. one produced by the charge ($q'$) of an antiparticle at a very close distance.

We define a "vacuum level", $V_{vqv} = V_{vqn}(z)$, as the level at which the pair of vaculeons constituting a vacuuon are no longer attracted with one another, thus being (effectively) at an infinite separation. Accordingly, at this level an external charge $q$, oscillating at amplitude $z_v$ about its equilibrium position $z = 0$, just begins to be no longer attracted to the surrounding vacuuons\(^1\), but is subject to instantaneous collisions with the vacuuons only. Therefore, a charge $q$ at the vacuum level is free in the sense of (IV). The charges $+e, -e$ of the $p, e$ of the feature (iv) are therefore at the vacuum level; and they are in turn in their $n = 1$ stationary states as stated by (ii)-(iii). That is, for the charges of $p, e$, the $n = 1$ levels coincide with the vacuum level, $V_{vq1} = V_{vq0} = 0$, and $z_v = \mathcal{A}_q$, whence (iv) is furnished.

\(^1\) A "negative" $V_{vq0}$ strictly applies to $+q$ and has for $-q$ a relative meaning only due to the $V_{vq}$ asymmetry over $+q$ and $-q$; see further Appendix A.1.
By the solution (6), in zero external field the harmonic state of the charge at level \( n = 1 \) can only be promoted to higher levels by a discrete amount at a time, i.e. \( n \hbar \omega, n = 2, 3, \ldots \); or it will not be altered at all. The charge is however not restricted from being continuously promoted to higher energies if acted on by an unidirectional force \( F_n \) and, assuming a sufficiently large \( F_n \), may be driven momentarily to the mid point \( z_{1/2} = (Z_{i+1} - Z_i)/2 \) between site \( i \) and adjacent site \( i + 1 \) along a diffusion path. At \( z_{1/2} \), it experiences shortest distances to the neighbouring vacuums, and therefore a maximum potential \( V'_{q1m} = V'_q(1/2) \) between site \( i \) and adjacent site \( i + 1 \). The potential difference \( \Delta V_i(z_i) = V'_q(z_i) - V'_q(1/2) \) defines an energy barrier which the charge \( q \) must overcome to hop to an adjacent site, see Figure 1. Its height \( \Delta V_i(z_{1/2}) = V'_{q1m} - V'_q(1/2) \) and width, \( \delta_1 \), are both dependent on the instantaneous interaction of \( q \), while at \( z_{1/2} \), with the vacuums which have fluctuating configurations due to the influence of the random environmental fields and the instantaneous motion of the charge \( q \); their determination is beyond the scope of this paper.

In conformity with the observational vacuum, the vacuums are densely packed in a disordered fashion and, owing to the vacuums’ structure, are in zero external field electrically neutral and non-interacting, whence forming a perfect liquid[2]. The \( V_{qnn} \) is intermediate ranged (see Appendix A): the vacuums thus to good approximation present to \( q \) with an average structure. In the latter regard, and provided disorder effect is to be superimposed where in question (such as diffusion path), we may represent the vacuums, as a simplest illustration, as arranged on a simple cubic lattice of spacing \( b_v \). Accordingly, \( z_{1/2} = b_v \pm \frac{1}{2} \), and the oscillation amplitude of the charge \( q \) at \( n = 1 \) level is

\[
\mathcal{A}_{q1} = \frac{1}{2}(b_v - \delta_1)
\]  

With this \( \mathcal{A}_{q1} \), and the experimental rest masses of \( p \) and \( e \), \( M_p(= 938.27 \text{ MeV}) \) and \( M_e(= 0.511 \text{ MeV}) \) for \( M \) in (9c), we obtain for the charges \(+ e \) and \(- e:\)

\[
\beta_q = \frac{2Mc^2}{(F_1b_v/2)^2}; \quad f_1 = \frac{\mathcal{A}_{q1}}{b_v/2} = 1 - \frac{\delta_1}{b_v} \quad (q, M = + e, M_p; - e, M_e)
\]  

Values of \( \beta_q \) evaluated based on (13) for the charges of the IED proton \( p \), electron \( e \), antiproton \( \bar{p} \), and positron \( \bar{e} \), together with other parameters involved in this section, \( \Omega, \mathcal{A}_{q1}(\mathcal{A}_{q0}), \mathcal{M}_q, t_{\varphi 1.0} \), are tabulated in Table 1.

| \( q^{(a)} \) | IED Particle | \( M^{(a)} \) (MeV) | \( \Omega^{(b)} \) \( (10^{20} \text{I/s}) \) | \( \mathcal{A}_{q1}f_1^{(c)} \) \( (10^{-18} \text{m}) \) | \( \beta_q f_1^{(d)} \) \( (10^{23} \text{N/m}) \) | \( \mathcal{M}_q f_1^{(e)} \) \( (\text{kg}) \) | \( t_{\varphi 1.0}^{(f)} \) \( (\text{s}) \) |
|---|---|---|---|---|---|---|---|
| \(+ e\) | \( p \) | \( M_p \) 938.27 | 14280 | 0.5 | 12020 | 5.896 \times 10^{-22} | \infty (short) |
| \(- e\) | \( \bar{p} \) | \( M_p \) 938.27 | 14280 | 21.42 | 6.549 | 3.218 \times 10^{-25} |
| \(- e\) | \( e \) | \( M_e \) 0.511 | 7.778 | 0.5 | 6.549 | 1.083 \times 10^{-18} | \infty |
| \(+ e\) | \( \bar{e} \) | \( M_e \) 0.511 | 7.778 | 0.0116 | 12020 | 1.989 \times 10^{-15} |

(a) Experimental masses of \( p, \bar{p}, e, \bar{e} \) [1]. (b) After (9a). (c) Given by (12) for \( p, e \) and (16), (17) for \( \bar{p}, e \). (d) After (13a). (e) After (3c). (f) From (11) for \( p, e \) and the discussions before (16) and after (17) for \( \bar{p} \) and \( \bar{e} \).

Taking \((i)-(iv)\) together, the creation of particle \( p \) or \( e \) corresponds to the excitation from energy level \( n = 0 \) (the ground state) to \( n = 1 \) (the first excited state) of the charge \( q = + e \) or \( - e \) in its potential well \( V_{q+en} \) or \( V_{q-en} \), upon a minimum external energy supply \( \epsilon_{\text{exc.m}} = \hbar \omega_q \) = \( \epsilon_{q1} = M_p c^2 \) or \( M_e c^2 \). \( \epsilon_{\text{exc.m}} \) is thus used for overcoming the potential difference \( V_{q0} - V_{q1} = V_{q0} = 0 \), whence

\[
V_{q0} = -\epsilon_{\text{exc.m}} = -M c^2 \quad (q, M = + e, M_p; - e, M_e)
\]  

And the energy \( \epsilon_{q1} \) gained by the charge \( + e \) or \( - e \) corresponds to the total energy associated with the rest mass \( M_p \) or \( M_e \) of the resulting IED particle \( p \) or \( e \).
Figure 1. Vacuum potential functions $V_{\nu q}(\zeta_n)$ versus $\zeta_n$ given by (15) for (a) charge $+e$, and (b) charge $-e$. Used for the plot: $f_1 = 0.9$.

Placing (13a),(14) in (10), setting $\zeta_n = \sqrt{n}\zeta$, $\zeta = z/b_{\nu}$, we obtain the parameterised quantised vacuum potentials of the charges $+e$ and $-e$ respectively across the interstice about $\zeta_n = 0$,

$$V_{\nu qn}(\zeta_n) = M c^2 \left( -1 + \frac{4}{f_1^2} \zeta_n^2 \right) \quad (q, M = +e, M_p; -e, M_e; \ |\zeta| < \frac{1}{2}). \quad (15)$$

The function $V_{\nu qn}$ is completely specified by (15) except for $f_1$, depending on $\delta_1$ through (13b), that is yet to be determined. $f_1$ affects the steepness of the $V_{\nu qn}$ well only; the energy levels of stable particle species (or particle states) therefore are completely specified by (15).

Equations (15), see also the graphical plots in Figure 1a,b, show a strong asymmetry of $V_{\nu qn}(\zeta_n)$ with respect to an external charge $+e$ and $-e$: $V_{\nu +e n}(\zeta_n)$ has a strongly negative depth $-M_p c^2 = -938.27$ MeV (Figure 1a), and $V_{\nu -e n}$ has a shallow ”negative” depth $-M_e c^2 = -0.511$ MeV (Figure 1b). This very asymmetry will be directly demonstrated in Appendix A.1 through a formal evaluation of the electromagnetic interaction for an external $q$ charge and vacuuon: an external positive charge $+q$ will be strongly attracted by the vacuum, while a negative charge $-q$ be strongly repelled therein. And this is a direct consequence of the asymmetric structure of the vacuuon, of which $-e$ envelops $+e$ (see Sec.4), combined with a ”strong force” effect which onsets at short interaction distances compared to the extension of the vacuuon.

As already entered as an input for the $V_{\nu qn}$ parameterisation, the proton lies at the first excited stationary state, i.e. energy level $n = 1$, of charge $+e$ in the $V_{\nu +e n}$ well, and the electron at level $n = 1$ of $-e$ in the $V_{\nu -e n}$ well, shown by the solid horizontal lines in Figure 1a and b. The very large mass ratio of $p$ over $e$, $M_p/M_e \approx 1836$, in retrospect, is a direct reflection of the asymmetry of the two vacuum potentials.

Based on the solutions (6), there is no stationary state below the level $n = 1$ for either charge. However, in a pair production out of a vacuuon (Sec. 4) in the vacuum, both its bound vaculeon charges $+e$ and $-e$ (assuming having been firstly disintegrated and now serving as two un-bound external charges) are by a resonance condition (see the end of Sec. 4) simultaneously excited with equal energies, provided a total energy $2 \times \varepsilon_{\text{exc}} = 2 \times h\omega_\gamma$ is externally supplied. If $\varepsilon_{\text{exc}}$ is
such that \(-e\) is excited to its \(n = 1\) level in the \(V_{\text{en}}\) well (Figure 1b), whence \(\omega_\gamma = M_e c^2/\hbar\) and the creation of a stable electron \(e\), then \(+e\) is excited by the same quantum \(\hbar \omega_\gamma\) in the \(V_{\text{en}}\) well (Figure 1a'), whence the creation of a positron \(\bar{e}\). The \(+e\) of \(\bar{e}\) is at the level \(V_{\text{en}} = V_{\text{en}}(A_{\text{ee}})\) (dotted horizontal line in Figure 1a'), and has an oscillation amplitude \(A_{\text{ee}}\). This \(\bar{e}\) state is far below the \(n = 1\) (proton) level in the \(V_{\text{en}}\) well, and is not a stationary state. But it would be virtually stable if, as is highly probable, the \(e\) simultaneously created has moved away and if also no other electron presenting nearby for annihilation. This \(\bar{e}\) will be "hidden" in the vacuum and not "free" in the sense said in (IV) earlier.

On the other hand, this excited charge \(+e\) of \(\bar{e}\) is free to travel from site to site at its own constant potential level \(V_{\text{en}}\), provided it has a sufficient kinetic energy to "hop" over a barrier (cf Figure 1a'), \(\Delta V_e = V_{\text{en}}'(z) - V_{\text{en}}(A_{\text{ee}})\) between each two sites. The oscillation amplitude of \(+e\) may be evaluated based on the energy equation for \(\bar{e}\), \(\frac{1}{2} \beta_{+e} A_{\text{ee}}^2 = M_e c^2\), given by using the \(\beta_{+e}\) given for \(+e\) in (13) but with the \(\varepsilon_{\text{exc}}\) equal to that of its opposite charge at level \(n = 1\) (i.e. \(M_e c^2\)) for \(\varepsilon_{q1}\), to be

\[
A_{\text{ee}} = \sqrt{2M_e c^2/\beta_{+e}} = \sqrt{(M_e/M_p) A_{\text{e1}}} = 0.0116 A_{\text{e1}},
\]

(16)

which is exceedingly small. The width of the barrier \(\Delta V_e\), \(\delta_e = b_v - 2 \times 0.01 A_{\text{e1}} \sim b_v\) (assuming \(\delta_1 < \frac{b_v}{2}\)), is thus wide. So after excited to above the barrier \(\Delta V_e\), the charge will be translating across the large distance \(\delta_e \sim b_v\) before entering next \(V_{\text{en}}\) well. From the experimental decay processes of the subatomic particles (e.g. [1]), we observe that, if disregarding the mediators \(W^\pm\), \(\bar{e}\) is in fact the only non-composite particle formed of \(+e\) which is below the \(n = 1\) level in the \(V_{\text{en}}\) well. All of the other mass-deficit subatomic particles like \(\pi^+, K^+, p\), manifestly having one-unit charges \(+e\)’s, are apparently composite particles built ultimately of a lepton \(\mu\) and its neutrino, with \(\mu\) being built of charge \(-e\) in the \(V_{\text{en}}\) well.

If on the other hand \(\varepsilon_{\text{exc}}\) is such that \(+e\) is excited to the \(n = 1\) level in the \(V_{\text{en}}\) well (Figure 1a'), \(\omega_\gamma = M_p c^2/\hbar\) and the creation of a stable proton \(p\), then similarly by a resonance condition \(-e\) is simultaneously excited by the same energy in the \(V_{\text{en}}\) well (Figure 1b), whence the creation of an antiproton \(\bar{p}\). The charge \(-e\) of \(\bar{p}\) at the potential level \(V_{\text{en}} = V_{\text{en}}(A_{\text{en}})\) (dotted horizontal line in Figure 1b) and has an oscillation amplitude \(A_{\text{en}}\). Similarly from \(\frac{1}{2} \beta_{-e} A_{\text{en}}^2 = M_p c^2\), given by using \(\beta_{-e}\) in (8) and \(\varepsilon_{\text{exc}} = M_p c^2\), we formally obtain

\[
A_{\text{en}} = \sqrt{2M_p c^2/\beta_{-e}} = \sqrt{(M_p/M_e) A_{\text{e1}}} = 21.42 A_{\text{e1}},
\]

(17)

which is many times larger than \(A_{\text{e1}}\) of the charge \(-e\) of electron \(e\), as is an inevitable result for \(V_{\text{enp}} >> V_{\text{e1}}\).

Since however the vacuum potential has a mean translation periodicity \(b_v\) along any diffusion path and thus is only quadratically well defined up to the vacuum level plus a \(\Delta V_1\), about \(z = \frac{b_v}{2}\), the charge \(-e\) of \(\bar{p}\) of the exceedingly large \(A_{\text{en}}\) factually traverses many potential wells in each quart of its one oscillation period. This motion is no longer properly harmonic; and higher stationary levels than 1, i.e. \(n = 2, 3, \ldots\), become unphysical except in the moments of charge–vacuum head-on collisions. The charge \(-e\) of \(\bar{p}\) accordingly will be so energetic as to translate from site to site swiftly, meeting and scattering with other particles frequently, thereby losing its energy, until settling down at the next and actually the only lower level of stationary state in the \(V_{\text{en}}\) well, which is the \(n = 1\) or electron state. That is, the resulting antiproton is short-lived and briefly will descend into a stable electron. This could explain the prominent "missing" of the antiprotons \(\bar{p}\)’s if all the protons present in nature are indeed produced in \(p – \bar{p}\) pair productions.

The above scheme can similarly account for the short lifetimes of the other observational heavier-mass, non-composite subatomic particles made of one-unit charges, actually the leptons
μ, τ only which are built of one-unit −e in the V_{\text{vac}} well, if disregarding the mediators, similarly based on the experimental decay processes of subatomic particles. All the other heavier-mass baryons such as Ω, A's, Σ's and mesons such as π, D^{\pm}, etc. having either one-unit −e or (as earlier remarked) +e, are apparently composite particles ultimately built of μ's and their neutrinos.

4. Vacuuonic potentials. Possible scheme for pair production

A vacuuon (e.g. v_{1} in Figure 2a) by construction[2, 9] consists of a positive charge +e seated on a minute sphere of radius r_{p v} at the centre, and a negative charge −e on a concentric spherical shell of thickness 2r_{o} and radius r_{n v} about p_{v}, termed as a p-vaculeon (p_{v}) and n-vaculeon (n_{v}). The p_{v}, n_{v} have spins \frac{1}{2} each; in their bound state in a vacuuon their spin magnetic moments are oriented in opposite directions in each others’ magnetic fields. The vacuuon structure, as a building entity of the substantial vacuum, is constructed based on overall experimental indications, most directly the pair production and annihilation experiments in particular[2, 9, 13]; see further the discussion after (20) later.

The r_{p v}, r_{n v} represent the most probable radii of the practically extensive p_{v}, n_{v} (similarly as the single charge q in Sec. 2) at the scale b_{v}, and r_{o} is said in a similar sense. We presently lack experimental information either on their direct values or for their theoretical evaluation; although definitely they must be (much) smaller than \frac{b_{v}}{2}. For the illustration below we shall take the r_{p v}, r_{o} values by their average, \frac{1}{2}(r_{p v} + r_{o}) = \sigma. And we set the vacuum radius r_{v} = r_{n v} + r_{o}, as the contact radius of the vacuuons on a simple cubic lattice (Sec. 3), so r_{v} = \frac{b_{v}}{2}, see Figure 2a. The focus of our discussion below will be to demonstrate the characteristics of the interactions rather than to perform an accurate numerical calculation.

In zero external field, the two vacuuon charges +e and −e of a vacuuon, say the v_{1} at z = 0 in Figure 2a, interact each other by a Coulomb attraction, \gamma_{p v n v}^{\text{cold}} = -\frac{e^{2}}{4\pi\epsilon_{0}r_{v}} = u_{0}\frac{\sigma^{2}}{r_{v}} = u_{1}\frac{\sigma^{2}}{r_{v}}, and a short range repulsion, \gamma_{p v n v}^{\text{rep}} = gu_{1}(\frac{\sigma}{r_{v}})^{N}, where u_{o} = \frac{e^{2}}{4\pi\epsilon_{0}(b_{v}/2)} = 2879.9 MeV for \rho_{v} = \frac{b_{v}}{2} = 0.5 \times 10^{-18} m, u_{1} = u_{o}(r_{v}/\sigma), and g = \frac{\sigma^{2}}{4\pi\epsilon_{0}r_{v}} = \frac{\sigma^{2}}{4\pi\epsilon_{0}r_{n v}} is the fraction of charge of the segment, of size πσ^{2} on the extensive n_{v} shell of an area 4πr_{n v}^{2}, which makes direct contact with p_{v}. The N, σ values are to be determined. The total p_{v}, n_{v} interaction potential energy per vacuuon is thus

V_{p v n v}(r) = \frac{1}{2}(\gamma_{p v n v}^{\text{rep}}(r) + \gamma_{p v n v}^{\text{cold}}(r)) = u_{1} \left[ g \left( \frac{\sigma}{r_{v}} \right)^{N} - \frac{\sigma}{r_{v}} \right] (18)

See also the graphical plot of V_{p v n v}(r) in Figure 3a (solid curve 1), where N = 12 (Lennard-Jones’ value) and \sigma = 0.1b_{v} are used for the illustration.

At r >> r_{p v}, n_{v} is acted on by p_{v} by (mainly) an attractive force F_{p v n v} = -\frac{\partial V_{p v n v}}{\partial r} \approx -\frac{\partial V_{p v n v}^{\text{cold}}}{\partial r}, where \gamma_{p v n v} = 2V_{p v n v}. This, in the zero mass representation, is counterbalanced by a magnetic force F_{m} on the spinning n-vacuuon charge on the spherical envelope in the magnetic field produced by spinning motion of p-vacuuon charge (Appendix A of [2]), F_{m} = -F_{p v n v}. The equality defines the equilibrium radius r_{n v}(= \frac{b_{v}}{2} - \sigma), at which \gamma_{p v n v}(r_{n v}) = -u_{1}(\sigma/r_{n v}) = -3599.9 MeV, or V_{p v n v}(r_{n v}) = -1799.9 MeV; accordingly, n_{v} has a spin kinetic energy E_{nk} = \frac{1}{2}\gamma_{p v n v}^{\text{rep}} and Hamiltonian E_{nk} = \gamma_{p v n v}^{\text{rep}} + E_{nk} = \frac{1}{2}\gamma_{p v n v}^{\text{rep}}. This \gamma_{p v n v}^{\text{rep}}, of a GeV scale, is far too deep for the vacuuon pair to be disintegrated to the vacuum level, by merely a supply of an excitation energy 2\varepsilon_{exc.m} given by (14), or

2 \times \varepsilon_{exc} = 2 \times h\omega_{\gamma} \geq 2 \times M c^{2} = \frac{1}{2} \beta_{q}(\sqrt{2}\alpha_{q})^{2} \quad (M = M_{p}, M_{e}; q = +e, \mp e) (19)

which are 2 \times 938.27, 2 \times 0.511 MeV for the \mp \bar{p}, e-\bar{e} pair productions. This 2\varepsilon_{exc} is merely enough to impart masses to a pair of dissociated vacuuon charges.
Figure 2 (left graphs). Vacuuons $v_1$, with $v_1$ at $z = 0$, arranged on a simple cubic lattice (a) in zero external field, and (b)–(c) in the field of an external charge $+q$ in the interstice $B$; $+q$ is moving toward $v_1$ at a finite velocity. In (c), $+q$ has collided with $n_v$ and in turn knocked $n_v$ into colliding with $p_v$ to their closed approaches each; at the same time, a $2\gamma$ wave of energy $2\hbar \omega_\gamma (\geq 2Mc^2)$ is incident on to $v_1$.

Figure 3 (right graphs). (a) Solid curve: $p_v - n_v$ interaction potential $V_{p_v,n_v}(\zeta)$ given by (18) for vacuuon $v_1$ in zero external field (as in Figure 2a), $\zeta = r/b_v$. Dashed curve 2 and dotted curve 3 ($\zeta > r_v$): potential energies of $p_v$ and $n_v$ of $v_1$, $V_{p_v,n_v,+q}(\zeta)$ and $V_{n_v,p_v,+q}(\zeta)$ given by (A.3)–(A.4) in the field of external charge $+q$ as in Figure 2b. The rapid rising part of curve 2 and curve 3' the two potentials $V_{p_v,n_v,+q}(\zeta)$ and $V_{n_v,p_v,+q}(\zeta)$ when $+q$, $n_v$ and $p_v$ are as positioned in Figure 2c. Corresponding curves 2, 3' for $-q$ are shown in (a'). Short-dot-dashed curves: the function $V_{n_v} + q$ in (a) and $V_{p_v} - q$ in (a') given by (14). Used for the plots: $\sigma = 0.1b_v$ (thus $u_1 = 14400$ MeV), $N = 12$, $d = 0.01b_v$. At $r_m = (gN)^{-\frac{1}{4} - 3\zeta}$, $V_{p_v,n_v,m}(r_m) = \frac{-u_1}{2} (gN)^{-\frac{1}{4} - 3\zeta} = -0.534r_1$. (b) Interaction potential $V_{v_1,+q}$ (solid curve), given by (A.2b), between vacuuon $v_1$ and external charge $+q$ of position $\zeta$ as in Figure 2b; and $V_{v_1,-q}$ (dashed curve) between $v_1$ and $-q$. Values used for the plots are as in (b).
Inevitably, before the condition (19) becomes legible, an additional energy, as enormous as 
2 × \((V_{\gamma 0} - V_{p+n_s}(r_n))\) \(\sim 3600\) MeV for \(e-\bar{e}\) production or 1720 MeV for \(p-\bar{p}\) production, needs 
firstly be supplied so as to disassociate the pair of bound vaculeons of the \(v_1\) here to at or above 
the ground state of the charge, \(V_{\gamma 0}\). Such an enormous energy may be practically supplied 
if the two vaculeons are simultaneously approached by a charged particle (e.g. a nucleon) \(q\) 
at very short distance and thereby repelled to above \(V_{\gamma 0}\); an external \(q\) thus needs be in the 
proximity (like the +\(q\) in the interstice \(B\) in Figure 2b) and moving at an adequate speed toward 
\(v_1\). A possible such process is illustrated in Figure 2c. The corresponding potentials of \(p_n, n_s\) 
in the presence of +\(q\), of coordinate \(z\), and similarly of -\(q\), \(V_{p+n_s, z}(z), V_{n,n+s,z}(z)\) as functions 
of the position \(z\) of +\(q\) or -\(q\) are given by (A.3)–(A.4), Appendix A.2. As the graphical plots, 
the dashed curves 2 and dotted curves 3 to 3' in Figure 3a,a' directly show, the two potential 
functions rise each rapidly to above \(V_{\gamma 0}\) at the closest approach between +\(q\), \(n_s\), and \(p_s\) (Figure 
2c), i.e. at \(z \sim 3\sigma\). The vaculeons \(p_s\) and \(n_s\) are now effectively no longer bound each other, 
being as if separated infinitely apart.

If these, as soon after their dissociation, are impinged by a \(\gamma\) wave (see Figure 2c) of an 
energy \(2\varepsilon_{\text{exc}} = 2h\omega_p\) fulfilling (19), e.g. \(\omega_p = m_p c^2/h\), then upon absorption of \(2\varepsilon_{\text{exc}}\) by a 
"resonance condition" (see below) the vaculeon charges +\(e\), -\(\bar{e}\) will have been each endowed with 
an oscillation energy \(h\omega_p = m_p c^2\). +\(e\) is now promoted to the energy level \(n = 1\) in the \(V_{\gamma + e}\) 
well at one site (short-dot-dashed curve in Figure 3a); and -\(\bar{e}\) to the level of \(p\) in the \(V_{\gamma - e}\) well, 
by a probable tendency, in another site located in the opposite direction to the displacement of 
+\(e\), since the charges +\(e\), -\(\bar{e}\) producing (or absorbing) the same radiation \(E\) field have opposite 
oscillation displacements. And similarly for \(\omega_p = m_e c^2/h\), with the charge -\(\bar{e}\) promoted to level 
\(n = 1\) in the \(V_{\gamma - e}\) well (short-dot-dashed curve in Figure 3a'), and +\(e\) to the level of \(\bar{e}\) in the 
\(V_{\gamma + e}\) well. These are the \(p-\bar{p}\) and \(e-\bar{e}\) pair productions of the reaction equations 
\[
2\gamma \rightarrow p + \bar{p}, \quad 2\gamma \rightarrow e + \bar{e}.
\]
The pair of particles produced will be at rest if \(\Omega = Mc^2/h\) or will have a residual velocity 
\(v = c\sqrt{1 - 1/\gamma^2}\) if \(\omega = \gamma \Omega > \Omega\), i.e. \(\gamma > 1\).

The reaction equations (20), together with the preceding energy criterion (19) and the 
requirement for the presence of a nucleus (or nuclei) in a pair production, are in complete 
agreement with experiment. Entirely as an experimental reaction equation, (20) are expressed 
such that they each inform explicitly all of "observables" before and after a pair production. In 
picular, (20) inform that both charges (+\(e\), -\(\bar{e}\)) and spins (\(\frac{1}{2}, \frac{-1}{2}\)) are present on their right-hand sides, but not the left-hand sides. And the external energy supply \(2\varepsilon_{\text{exc}} = 2Mc^2\) is only to 
ascribe dynamical masses to the pair of vaculeon charges +\(e\), -\(\bar{e}\) (which have zero rest masses), 
or equivalently, (dynamical) rest masses to the resulting IED particles in each reaction process, 
\(e, \bar{e}\) or \(p, \bar{p}\). So the charges +\(e\), -\(\bar{e}\) which carry a potential energy \(V_{p,n_s}(r_n)\) at the particles' 
production as given by (18), and their spins \(\frac{1}{2}\)'s which carry a kinetic energy, must exist in the 
vacuum, whence the vaculeons composing a vacuum, so as to satisfy the requirement of energy 
conservation. Similar discussion was made for the pair annihilation in [2, 9, 13].

Supplemental remarks regarding the pair production: (i) The resonance condition. In 
mechanical terms, as follows from Sec. 2, the dielectric vacuum is induced with an elasticity in 
the presence of an external charge \(q\) nearby. And the electromagnetic \(\gamma\) wave, of a wavelength 
\(\lambda_\gamma \sim 1.3 \times 10^{-15}\) or \(\sim 2.4 \times 10^{-12}\) m, is an elastic wave propagated in the vacuum by means 
of vacuum deformations, or in other terms, of the oscillations of coupled oscillators each composed 
of (tremendously) many vacuuons (of size \(\sim 10^{-18}\) m each). So relative to the extensive \(\gamma\) wave, 
the pair of vaculeons \(p_s, n_s\) in a vacuuon (the \(v_1\) above) are just a minute point on a large 
oscillator. They will respond to the \(\gamma\) wave as one point, practically the only point in the large 
oscillator being in the (internal) mode of resonance absorption to the quanta \(2h\omega_r\) of the \(\gamma\) wave, 
assuming no other bound vaculeons in the large oscillator are dissociated to above level \(V_{\gamma 0}\).
(ii) The incident $\gamma$ wave of energy $2\varepsilon_{exc}$ is an extensive electromagnetic wave train (as schematically shown in Figure 2c) of length $L_\gamma$ and effective amplitude $A_{q1} = \frac{\sqrt{2}}{\sqrt{L_{\gamma}}} \alpha_{q1}$ [16]. Accordingly, the "absorption of $2\varepsilon_{exc}$" is a gradual, continuous process spanning a total duration $t_{\gamma1.0}$, in which the wave train front runs at the velocity of light $c$ on to the two vaculeon charges $+e$ and $-e$ of $v_1$, and be thereby absorbed by them (by a certain fraction) continuously. Two new waves of the same $\omega$, and of amplitude $A_{q1}$ each, are subsequently continuously re-emitted by the two charges, and then, together with the transmitted fraction, re-absorbed after reflecting back from surrounding walls.

(iii) At the end of one $t_{\gamma1.0}$, two full wave trains (i.e. for the fraction $a_1 + a_2 = 1$) maintain the same $L_\gamma$, and same total $2\varepsilon = 2mc^2$, and $2p = 2\varepsilon/c = 2mc$ (i.e. the linear momentum, which is conserved in this sense) as the incident one. These two wave trains have now become the respective (internal) components of the (IED) particle and antiparticle just produced.

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Appendix A. Electromagnetic interaction between a vacuuon and external charge
A.1 Interactions at larger distances up to a closest approach
As shown in Figure 2b (Sec. 4), the vacuuon $v_1$ at $z = 0$ is polarised by the external charge $+q$ in the interstice $B$, moving from initial position say $z = \frac{h}{2\sqrt{2}}$ toward $v_1$ at a finite speed. We shall express the $v_1---+q$ and $v_1---q$ interaction potentials in electromagnetic terms below, and shall do so by situating ourselves in the frame where the mass centre of $v_1$ is not moved during the interaction. (This frame approximately corresponds to the frame fixed to the vacuum if $v_1$ and its surrounding vacuuons cannot move freely due to attachment to a fixed matrix of charged particles, but their configuration may be locally deformed under the dynamical impact of $q$.) In this frame, the $p_1$ and $n_1$ vaculeons of the polarised vacuuon $v_1$ are displaced from the fixed position $z = 0$ to $-\frac{d}{2}$ and $+\frac{d}{2}$. Since $r_{n_1} >> \sigma$, we shall regard the $p_1$ and $q$ as point like and the $n_1$-shell spherical shell extensive in respect to their short range interactions.

$+q$ interacts with a charge element $dq_1$ on the extensive spherical shell of $n_1$ by a Coulomb attraction $dF = \frac{dq_1 \cdot dq}{4\pi\epsilon_0 r_{n_1}}$. Integration over the entire shell gives the total attraction of $+q$ and $n_1$ as $[2] F_{\pm} = -\frac{u_1\sigma}{2r_{n_1}^2}(\frac{r_{n_1}}{z})^n$, with $n = 15.7$, which is strongly short ranged (whence a "strong force"). Accordingly $V^{\text{coul}}_{n_1+q} = -\frac{1}{2} \int_{-\frac{d}{2}}^{+\frac{d}{2}} dz \pm -\frac{u_1\sigma}{2r_{n_1}^2}(\frac{r_{n_1}}{z})^n$. Because of the simple symmetry of the $n_1$-shell with respect to $q$, for a better physical transparency we below express this interaction alternatively by representing $n_1$ effectively as two one-half charges $\frac{\pm}{2}$, $\frac{\pm}{2}$ projected on the $z$ axis at $-r_{n_1} + \frac{\pm}{2}$, with $r_{n_1} = r_v/2[2]$, as

$$V^{\text{coul}}_{n_1+q} = -\frac{u_1}{4} \left[ \frac{\sigma}{z + \frac{\pm}{2}} + \frac{\sigma}{z - \frac{\pm}{2}} \right] = -\frac{u_1\sigma\eta}{2(z - \frac{\pm}{2})^2}, \quad \eta = \frac{1}{1 - (r_{n_1}/(z - \frac{\pm}{2}))^2}. \quad (A.1)$$
In addition, $+q$ interacts with $n_e$ similarly through $n_v$ of a fractional charge $gq$ as in (18) by a short range repulsion, $V_{n_v+q}^{\text{rep}} = \frac{u_1}{2} g \left( \frac{\sigma}{z - (r_{n_v} + \frac{d}{2})} \right)^N$. And, with the $n_e$-shell in between, $+q$ interacts with $p_v$ by a Coulomb repulsion only, $V_{p_v+q}^{\text{coul}} = \frac{u_1}{2} \frac{\sigma}{z + \frac{d}{2}}$ for $z \geq 4\sigma$. Adding the terms above, we obtain the interaction potential energy of $+q$ with vacuum $v_1$, and similarly of $-q$ with $v_1$ after corresponding sign changes, as

$$V_{v_1+q} = V_{n_v+q}^{\text{rep}} + V_{p_v+q}^{\text{coul}} + V_{n_v+q}^{\text{coul}} = \frac{u_1}{2} \left[ g \left( \frac{\sigma}{z - (r_{n_v} + \frac{d}{2})} \right)^N + \frac{\sigma \eta}{z (z + \frac{d}{2})} \pm \frac{\sigma}{(z \mp \frac{d}{2})^2} \right], \quad (A.2)$$

where $(A.2b)$ is given after expanding the second and third terms of $(A.2a)$ in $\frac{d}{2}$ and retaining the respective two first leading terms. The last term in $(A.2b)$, $-\frac{u_1 \sigma \eta (\eta + 1)}{4z^2}$, represents the interaction energy of the $n_e$ vacuole dipole moment, $p_{n_v} = ed\hat{z}$, with the static Coulomb field of charge $q$, $E_q = \frac{u_1 \sigma (\eta + 1)}{2z^2} \hat{z}$, and this may be directly obtained as $V_{\text{dip}} \cdot \mathbf{E}_q = \frac{u_1 \sigma (\eta + 1)}{4z^2}$. Since for small $d$ there is always $\eta > (\eta + 1)$, at $z < \frac{d}{2} > r_{n_v}$, $V_{\text{dip}} \cdot \mathbf{E}_q$ is thus an attraction for either $+q$ or $-q$. The second term in $V_{v_1+q}$ of $(A.2b)$, $\pm \frac{\sigma}{(z \pm \frac{d}{2})^2} = V_{\text{coul}}^{n_v+q}$ is a main attraction term between $v_1$ and $+q$, and is a repulsion between $v_1$ and $-q$. The sum of the interactions of $q$ with all surrounding vacuums up to an intermediate range, $V_{v_1+q}$, gives the $V_{v_1+q}$ of Sec. 2.

As the graphical plots in Figure 3b directly show, from larger $z$ down to a closest approach at $z = r_v$, the potential $V_{v_1+q}$ (solid curve) for the positive charge $+q$ is strongly negative, while $V_{v_1+q}$ (dotted curve) for $-q$ is positive for a wide range of $d$ value ($d = 0.01b_v$ for the plots).

### A.2 Dynamical interactions after $q, n_e$ closest approach

At about $z = r_v$, $+q$ and the segment $n_{\text{eff}}^v$ of the $n_e$-shell (cf Figure 2c) are at closest approach. And the $+q - n_v$ interaction potential, $V_{n_v+q} = V_{n_v+q}^{\text{rep}} + V_{n_v+q}^{\text{coul}}$ as given by the sum of first two terms in $(A.2a)$, shown by the dotted curve 3 in Figure 3a, rises rapidly.

From $z = r_v$ downward, $+q$ continues to move toward $p_v$, now together with $n_e$ while impressing on the segment $n_{\text{eff}}^v$ (which has the coordinate $z' = z - 2\sigma$) of $n_v$ a constant repulsion $V_{n_{\text{eff}}^v}^{\text{rep}}(z - z') = g \left( \frac{\sigma}{z - 2\sigma + \frac{d}{2}} \right)^N$ (with the steep step of the dotted curve 3 sweeping across the region, ending at curve $3'$). In addition, $+q$ interacts with $n_v$ by a Coulomb potential $V_{n_{\text{eff}}^v}^{\text{coul}}(z) = -\frac{u_1 \sigma}{2(r_{n_v} - z)}$ as given after (A.1); and with $p_v$ by the $V_{p_{n_v}+q}^{\text{coul}} = \frac{u_1 \sigma}{2(z + \frac{d}{2})}$ as before. $p_v$ interacts with $n_v$, a very crude approximation here, by the constant Coulomb potential $V_{p_{n_v}+q}^{\text{coul}}(r_{n_v}) = -\frac{u_1 \sigma}{2 r_{n_v}} = -1799.9$ MeV, and with the segment $n_{\text{eff}}^v$ of $n_v$ by a short range repulsion $V_{p_{n_v}+q}^{\text{rep}}(z') = \frac{u_1}{2} g \left( \frac{\sigma}{z - 2\sigma} \right)^N$. Adding the respective terms above, the total potentials of $p_v$ and $n_e$ as functions of the coordinate $z$ of $+q$ are

$$V_{p_{n_v}+q}(z) = V_{p_{n_v}+q}^{\text{rep}}(z') + V_{p_{n_v}+q}^{\text{coul}}(r_{n_v}) + V_{n_{\text{eff}}^v+q}^{\text{coul}}(z) = \frac{u_1}{2} \left[ g \left( \frac{\sigma}{z - 2\sigma + \frac{d}{2}} \right)^N - \frac{1}{2} \frac{\sigma}{r_{n_v}} + \frac{\sigma}{(z + \frac{d}{2})^2} \right], \quad (A.3)$$

$$V_{n_{p_v}+q}(z) = V_{n_{p_v}+q}^{\text{rep}}(z') + V_{n_{p_v}+q}^{\text{coul}}(z - z') + V_{n_{p_v}+q}^{\text{coul}}(r_{n_v}) + V_{n_{p_v}+q}^{\text{coul}}(z - z') \quad = \quad \frac{u_1}{2} \left[ g \left( \frac{\sigma}{z - 2\sigma + \frac{d}{2}} \right)^N + \left( \frac{1}{2} \frac{\sigma}{r_{n_v}} - \frac{\sigma}{z - \frac{d}{2}} \right) \right]. \quad (A.4)$$

These are plotted by the dashed curve 2 and dotted curves 3-3’ in Figure 3a. When $+q$ is at $z = z' + 2\sigma = 4\sigma - \frac{d}{2}$, $n_{\text{eff}}^v$ is at $z' = z - 2\sigma = 2\sigma - \frac{d}{2}$ and touches $p_v$, producing on $p_v$ a strong short range repulsion $V_{p_{n_v}+q}^{\text{rep}}(z' = 2\sigma - \frac{d}{2}) = \frac{u_1}{2} g \left( \frac{\sigma}{z - 2\sigma + d/2} \right)^N$. 


Appendix B. Diffusion current of complex fluid

Let \( \rho_A(z, t) \) be the density of a real fluid in flow motion at velocity \( v \) in \( z \) direction with a flow rate \( j_A = \rho_A v \). \( j_A \) may be alternatively written as a diffusion current \( j_A = -D_A \nabla \rho_A \) (Fick’s first law), where \( D_A \) is a real diffusion constant; and \( j_A \) is positive in the direction in which the density gradient decreases. Let \( \rho_A \) be written as \( \rho_A = A^A A \) where \( A', A \) are two arbitrary differentiable real functions of \( z \). Then

\[
\dot{j}_A = -D_A [\nabla (A') A + A' (\nabla A)] . \tag{B.1}
\]

If now it is a “complex” fluid of density \( \rho_q = \psi^*_q \psi_q \), where \( \psi_q(z, t) = e^{i\omega t} \phi_q(z) \) and \( \psi_q^* \) are the complex functions as in Sec. 2, and we want to write down a positive diffusion current \( j_q \) associated with \( \rho_q \) on an equal footing with (B.1), certain transformations must be involved as we proceed as follows. Firstly, since \( z(t) = v_q t \), \( v_q \) being the flow velocity in \( z \) direction, thus \( e^{i\omega t} = e^{i\omega z/v_q} \); accordingly \( \psi_q(z, t(z)) \rightarrow \psi_q(z), \psi_q^* \rightarrow \psi^*_q(z) \), and \( \rho_q \rightarrow \rho_q(z) \); i.e., \( z \) is now an explicit independent variable of \( \rho_q \) similarly as of \( \rho_A \) in (B.1). We further define (for reason to become evident in the end) an imaginary diffusion constant, \( D_q = i|D_q| \). We can now make three immediate substitutions of variables in (B.1) with corresponding ones for \( \rho_q \), in such a way that each term is ensured real and having a correct sign so as to finally achieve a \( j_q \) in accordance with the definition of (B.1):

\[
D_A \rightarrow |D_q| = -iD_q, \quad A' \rightarrow \psi^*, \quad A \rightarrow \psi. \tag{B.2}
\]

The derivatives of \( \psi_q \) and \( \psi_q^* \) will however introduce an imaginary index \( i \) and sign into the coefficients, as \( \frac{1}{i} \psi_q = -i \psi_q \), \( \frac{1}{i} \psi^* = i \psi^* \). To obtain their “positive and real” values we rotate the two functions in the complex plane by angles \( +\frac{\pi}{2} \) and \( -\frac{\pi}{2} \), thus

\[
\nabla A' \rightarrow i \nabla \psi^*, \quad \nabla A \rightarrow -i \nabla \psi; \quad -\nabla \rho_q \rightarrow -\nabla \rho_A = -[(i \nabla \psi^*) \psi + \psi^*(-i \nabla \psi)] . \tag{B.3}
\]

With (B.2),(B.3) in (B.1), we obtain

\[
\dot{j}_q = -|D_q| \nabla \rho_q = -(iD_q) [(i \nabla \psi^*) \psi + \psi^*(-i \nabla \psi)] = -D_q[(\nabla \psi^*) \psi - \psi^*(\nabla \psi)] . \tag{B.4}
\]

Appendix C. Radiation emission time by quasi harmonically oscillating charge

Suppose that (i) the \( F_{ext} \) in (3), Sec. 2, is not zero but is equal to a radiation damping force, \( F_{ext} = F_{rad} = -\omega \partial \nabla \partial \overline{\partial \overline{\partial \phi}} \), where \( \omega_r \) is a radiation damping factor, (ii) \( \omega_r/\omega \ll 1 \), so the equations of motion and the solutions of Sec. 2 continue to hold over a finite time interval in which damping of amplitude is negligible, whence a quasi stationary radiation, and (iii) we restrict as before (Sec. 2) to the excitations which create matter particles only. Then, the energy solution for (3) combined with (2) of the now quasi-harmonically oscillating charge is at any time \( t_s \) given as, dropping a term \( \frac{1}{2} \hbar \omega \) similarly as in (6),

\[
\varepsilon_q^{(n)}(t_s) = e^{-\omega_r t_s} \varepsilon_q^{(n)}, \quad \varepsilon_q^{(n)} = n \hbar \omega, \quad n = 1, 2, \ldots \tag{C.1}
\]

If at initial time \( t_s = 0 \) the charge is at level \( n \) and just begins to emit radiation, and after a time \( t_s = t_{\varepsilon,n-1} \) it has emitted one entire energy quantum \( \Delta \varepsilon^{(n-1)} = n \hbar \omega - (n - 1) \hbar = \hbar \omega \), whence transforming to level \( n - 1 \), the energy reduction given after (C.1) is

\[
\Delta \varepsilon^{(n)}(t_{\varepsilon,n-1}) = n \hbar \omega(1 - e^{-\omega_r t_{\varepsilon,n-1}}) . \tag{C.2}
\]

But \( \Delta \varepsilon^{(n)}(t_{\varepsilon,n-1}) = \Delta \varepsilon^{(n-1)} \); or, \( n \hbar \omega(1 - e^{-\omega_r t_{\varepsilon,n}}) = \hbar \omega \). This gives

\[
t_{\varepsilon,n-1} = -\frac{1}{\omega_r} \ln \frac{n}{n - 1} . \tag{C.3}
\]
References

[1] Nakamura K et al (Particle Data Group) 2010 J. Phys. G: Nucl. Part. Phys. 37 075021; P J Mohr 2008 CODATA recommend values of the fundamental physical constants: 2006" Rev. Mod. Phys. 80, 633-730; D. Griffith 1987 Introduction to elementary particles (Harper and Row Publisher); D Brune, B Fordman, B Persson 1984 Nuclear Analytical Cemetery (Studentlitteratur, Lund); E Rutherford 1919 Phil. Mag. 37 581; J J Thomson 1897 Phil Mag 44 293.

[2] Zheng-Johansson J. X. and P-I. Johansson 2006 Unification of Classical, Quantum and Relativistic Mechanics and of the Four Forces (Nova Sci. Pub. Inc., N. Y.). Zheng-Johansson, J.X. 2003 Unification of Classical and Quantum Mechanics & The Theory of Relative Motion Bullet Amer. Phys. Soc. G35.001 General Physics, March; Zheng-Johansson, J.X., P-I Johansson, (Feb 24) 2003 Unification Scheme for Classical and Quantum Mechanics at All Velocities (I) fundamental construction of material particles, submitted to Proc Roy Soc Lond..

[3] Zheng-Johansson, J. X. 2006 Inference of Basic Laws of Classical, Quantum and Relativistic Mechanics from First-Principles Classical-Mechanics Solutions (Nova Sci. Pub., Inc., N. Y.).

[4] Zheng-Johansson J. X. and P.-I. Johansson 2006 Inference of Schrödinger equation from classical mechanics solution Suppl. Blug. J. Phys. 33, 763, Quantum Theory and Symmetries IV.2, ed. V.K. Dobrev (Heron Press, Sofia), p763 (Preprint arxiv:physics/0411314v5).

[5] Zheng-Johansson J. X. and P.-I. Johansson 2006 Developing de Broglie wave Prog. Phys. 4, 32 (Preprint arxiv:physics/0608265).

[6] Zheng-Johansson J. X. and P.-I. Johansson 2006 Mass and mass–energy equation from classical-mechanics solution Phys. Essays 19, 544 (Preprint arxiv:physics/0501037).

[7] Zheng-Johansson J. X. 2006 Prog. Phys. 3, 78 (Preprint arxiv:physics/060616).

[8] Zheng-Johansson J. X. 2008 Dirac equation for electrodynamical model particles J. Phys: Conf. Series 128, 012019, Proc. 5th Int. Symp. Quantum Theory and Symmetries, ed. M. Olmo (Valladolid, 2007).

[9] Zheng-Johansson J. X. 2007 Vacuum structure and potential Preprint arxiv:0704.0131.

[10] Zheng-Johansson J. X. 2006 Dielectric theory of the vacuum, Preprint arxiv:physics/0612096.

[11] Zheng-Johansson J. X. and P.-I. Johansson, R. Lundin 2006 Depolarisation radiation force in a dielectric medium. its analogy with gravity, Suppl. Blug. J. Phys. 33, 771; J. X. Zheng-Johansson and P.-I. Johansson, Gravity between internally electrodynamic Particles, Preprint arxiv:physics/0411245.

[12] Zheng-Johansson J. X. 2008 Doebner-Goldin Equation for electrodynamical model particle. The implied applications Preprint arxiv:0801.4279, Talk at 7th Int. Conf. Symm. in Nonl. Math. Phys. (Kyiv, 2007).

[13] Zheng-Johansson J. X. 2010 Internally electrodynamical particle model: its experimental basis and its predictions Phys. Atom. Nucl. 73 571-581 (Preprint arxiv:0812.3951), Proc Int 27th Int Colloq Group Theory in Math Phys (Ireven, 2008).

[14] Zheng-Johansson 2010 Self interference of single electrodynamical particle in double slit Preprint arxiv:1004.5000; Talk at Proc. 6th Int. Symp. Quantum Theory and Symmetries ed. A. Shapere and Das (Lexington, 2009).

[15] Zheng-Johansson J. X. 2010 Quantum-Mechanical Probability of IED Particle(s) Preprint arxiv: 1011.1344. Talk at 28th Int. Colloq. Group Theory in Math. Phys. (Newcastle, 2010).

[16] Zheng-Johansson J. X. 2011 Dynamics and radiation of harmonically oscillating charge of IED particle from a unified treatment (internal, 2011).

[17] The experimentally measured upper bound of electromagnetic radiation frequency is \(\nu_o \sim 5 \times 10^{25} \text{1/s} \) (see e.g. C Nordling and J Österman, Physics Handbook for Sci Eng, 6th Ed, Studentlitteratur, 1999, p53, Table 4.2); this gives the minimum wavelength \(\lambda_o = \frac{\nu}{\nu_o} = 6 \times 10^{-18} \text{m} \). A vacuum continuum able to propagate a wave of this shortest-wavelength should have a spacing \(b_v \) at least several times smaller than \(\lambda_o \). Taking the scaling factor to be 6 here, we have \(b_v = \lambda_o/6 = 1 \times 10^{-18} \text{m} \).

[18] Merzbacher E. 1970 Quantum Mechanics (John Wiley and Sons, Inc.) p. 57.