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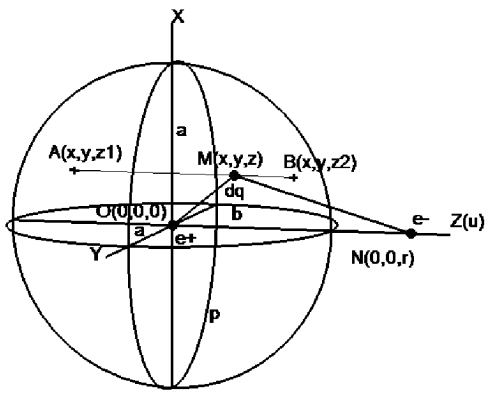

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QUANTUM FIELD THEORY FOR GRAVITY AS SCALAR FIELD

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Newton's gravitational theory is regarded as a linear approximation of general relativity. Therefore the quantization of scalar gravitational field in Newton's theory is also thought to be an approximation of that of general relativity. Under that approximation, the relation of inertial mass and gravitational mass is discussed from the viewpoint of quantum field theory. It is shown that the terms of inertial mass and gravitational mass in Lagrangian follow the same gauge transformation. The scattering amplitude for the interaction mediated by the gauge field derived from that gauge transformation is calculated in some examples and the difference of that interaction from electric interaction is discussed on the process of renormalization.

1. Introduction

It is known that the quantization of gravitational field based on general relativity is difficult due to the non-linearity of field equations. On the other hand in classical dynamics, Newton's gravitational potential is a very accurate approximation of that derived from general relativity when the gravity is not extremely strong. Therefore the quantization of Newton's gravitational potential might give efficient approximation for that of actual gravitational field under appropriate conditions. Here the gauge field derived from Newton's gravitational potential and its quantization are discussed in parallel with quantum electrodynamics.

2. Lagrangian form for scalar gravitational field

Firstly we consider the following Lagrangian density of electron under electric interaction.

$$L = -(1/2)(\overline{\psi}\gamma_\mu\partial_\mu\psi - \partial_\mu\overline{\psi}\gamma_\mu\psi) - m\overline{\psi}\psi + \\ +ie\overline{\psi}\gamma_\mu A_\mu\psi, \tag{1}$$

where m is rest mass of electron; e is charge of electron.

We attempt to interpret the second term $-m\overline{\psi}\psi$ in the above Lagrangian density is caused from the interaction mediated by scalar gauge field. Namely we rewrite the above Lagrangian density as,

$$L = -(1/2)(\overline{\psi}\gamma_\mu\partial_\mu\psi - \partial_\mu\overline{\psi}\gamma_\mu\psi) + im\overline{\psi}(G'/\eta^2)\psi + \\ +ie\overline{\psi}\gamma_\mu A_\mu\psi, \tag{2}$$

where η is a real constant and G' is a scalar gauge field; η^2 and G' have the same dimension as force (i.e. $[E][l]^{-1}$). In this case G' is equal to $i\eta^2$, namely the imaginary scalar gauge field $G' = i\eta^2$ causes the effect of inertial mass on kinetic motion of electron. The actual value of η is discussed later. The scalar gauge field $G' = i\eta^2$ is universally constant field, however its value is imaginary and it doesn't correspond to Newton's gravitational potential explicitly. So we extend G' as varied by the coordinates. Thus the above Lagrangian density (2) is extended as,

$$\begin{aligned} L &= -(1/2)(\overline{\psi}\gamma_\mu\partial_\mu\psi - \partial_\mu\overline{\psi}\gamma_\mu\psi) + \\ &\quad +im\overline{\psi}(G(x)'/\eta^2)\psi + ie\overline{\psi}\gamma_\mu A_\mu\psi = \\ &= -(1/2)(\overline{\psi}\gamma_\mu\partial_\mu\psi - \partial_\mu\overline{\psi}\gamma_\mu\psi) + \\ &\quad +im\overline{\psi}((i\eta^2 + G(x))/\eta^2)\psi + ie\overline{\psi}\gamma_\mu A_\mu\psi = \\ &= -(1/2)(\overline{\psi}\gamma_\mu\partial_\mu\psi - \partial_\mu\overline{\psi}\gamma_\mu\psi) - m\overline{\psi}\psi + \\ &\quad +im\overline{\psi}(G(x)/\eta^2)\psi + ie\overline{\psi}\gamma_\mu A_\mu\psi. \end{aligned} \tag{3}$$

In the above Lagrangian density, the third term: $im\overline{\psi}(G(x)/\eta^2)\psi$ expresses the gravitational interaction on the electron from external source.

The Lagrangian density (3) is also deduced from the invariability of the Lagrangian density (1) over the gauge transformation: $\exp(-im\zeta(x))$. The gauge invariability requires substituting the partial differential ∂_μ as $\partial_\mu - im\partial_\mu\zeta(x)$. Therefore, setting $G(x)$ so as to satisfy the equation: $\partial_\mu\zeta(x) = \gamma_\mu G(x)/(4\eta^2)$, the Lagrangian density (1) is rewritten as,

$$\begin{aligned} L &= -(1/2)(\overline{\psi}\gamma_\mu\partial_\mu\psi - \partial_\mu\overline{\psi}\gamma_\mu\psi) - m\overline{\psi}\psi + \\ &\quad +im\overline{\psi}\gamma_\mu\gamma_\mu G(x)/(4\eta^2)\psi + ie\overline{\psi}\gamma_\mu A_\mu\psi = \\ &= -(1/2)(\overline{\psi}\gamma_\mu\partial_\mu\psi - \partial_\mu\overline{\psi}\gamma_\mu\psi) - m\overline{\psi}\psi + \\ &\quad +im\overline{\psi}(G(x)/\eta^2)\psi + ie\overline{\psi}\gamma_\mu A_\mu\psi (\Leftarrow \gamma_\mu\gamma_\mu = 4). \end{aligned}$$

The equation of kinetic motion under the gravity mediated by the field G is thought to be expressed as,

$$dP_\mu/d\tau = -m\partial_\mu G/\eta^2, \tag{4}$$

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where P_μ and τ are 4-momentum vector and proper time respectively. Also from the analogy with Maxwell's equations, $\partial_\mu G$ is thought to satisfy the following equation.

$$\partial_\mu \partial_\mu G = -\rho(x), \tag{5}$$

where $\rho(x)$ is the current of mass (unit: $[E][l]^{-3}$). If there isn't any mass on the field, then G satisfies,

$$\partial_\mu \partial_\mu G = 0.$$

This means the gravitational wave mediated by G has the light speed. The Lagrangian density inducing the equation (5) is expressed as,

$$L_G = -(1/2)\partial_\mu G \partial_\mu G + G\rho(x). \tag{6}$$

Since m/η and G/η have the dimensions of e and A_μ respectively, it is convenient for comparing electric interaction to rewrite the Lagrangian density (3) as,

$$\begin{aligned} L &= -(1/2)(\overline{\psi}\gamma_\mu \partial_\mu \psi - \partial_\mu \overline{\psi}\gamma_\mu \psi) - m\overline{\psi}\psi + \\ &\quad + i(m/\eta)\overline{\psi}(G(x)/\eta)\psi + ie\overline{\psi}\gamma_\mu A_\mu \psi. \end{aligned} \tag{7}$$

The above expression indicates the gravitational interaction and electric interaction have similar forms. Therefore we quantize G with similar way to that of the electromagnetic field [1] as,

$$[G(x)/\eta, G(y)/\eta] = iD(x-y),$$

where $D(x-y)$ is the invariant delta function, i.e. it satisfies the following equations:

$$\begin{aligned} \partial_\mu \partial_\mu D(x) &= 0; \\ D(0, \mathbf{x}) &= 0; \\ \partial_0 D(x)|_{x_0=0} &= -\delta^{(3)}(\mathbf{x}). \end{aligned}$$

Similar to the expansion of A_μ, G/η is expanded as,

$$G/\eta = G^{(+)}/\eta + G^{(-)}/\eta \quad \text{s.t.;}$$

$$\begin{aligned} G^{(+)}/\eta &= (2\pi)^{-3/2} \int_{k_0=K} d^3k (2k_0)^{-1/2} h(k) \times \\ &\quad \times (g^+(k)/\eta) \exp(-ik_j x_j); \\ G^{(-)}/\eta &= (2\pi)^{-3/2} \int_{k_0=K} d^3k (2k_0)^{-1/2} h(k) \times \\ &\quad \times (g(k)/\eta) \exp(ik_j x_j), \end{aligned} \tag{8}$$

where $K = (k_j k_j)^{1/2}$. $g^+(k)/\eta$ and $g(k)/\eta$ are creation and annihilation operators on the field G/η. It should be noticed that $h(k)$ in the above expressions is the scalar function of momentum, while $e(k)_{\mu\nu}$ corresponding to $h(k)$ in the expansion of gauge field A_μ expresses the polarization of photon and contributes to the change of spin. Namely the gravitational interaction mediated by G/η doesn't change the spin.

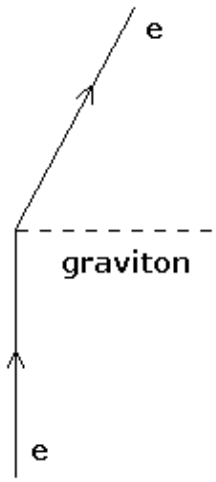

Figure 1: Feyman diagram for gravitational Rutherford scattering (1)

3. Scattering amplitude on gravitational interaction

Based on the similarity on the Lagrangian densities for gravitational interaction and electric interaction, we expand the Hamiltonian including quantized gravitational interaction with the similar way to that of quantized electric interaction. Firstly we discuss some examples of the first-order approximation of scattering amplitude on gravitational interaction.

A) Gravitational Rutherford scattering

From the above figure, the scattering amplitude is expressed as,

$$T_{fi} = i(m/\eta)\overline{u}_f u_i \int d^4x \ \exp(-iq_\mu x_\mu)(G(x)/\eta),$$

where u_i and u_f are the quantized fields of electron having constant momentum before and after scattering respectively. If G(x) doesn't depend on the time, the above scattering amplitude is rewritten as,

$$\begin{aligned} T_{fi} &= 2\pi\delta(E_f - E_i) i(m/\eta)\overline{u}_f u_i \times \\ &\quad \times \int d^3x \ \exp(iq_k x_k)(G(\mathbf{x})/\eta) = \\ &= 2\pi\delta(E_f - E_i) i(m/\eta)\overline{u}_f u_i (G(\mathbf{q})/\eta). \end{aligned}$$

From the equation (5),

$$\partial_\mu \partial_\mu G(x) = -\nabla^2 G(\mathbf{x}) = -\rho(\mathbf{x}),$$

hence,

$$\begin{aligned} \rho(\mathbf{q}) &= \int d^3x \exp(iq_k x_k)\rho(x) = \\ &= \int d^3x \exp(iq_k x_k)\nabla^2 G(\mathbf{x}) = -q_k q_k G(\mathbf{q}), \end{aligned}$$

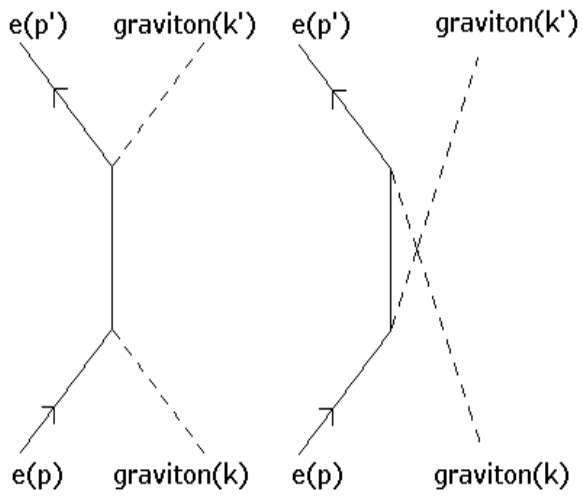

Figure 2: Feyman diagram for gravitational Compton scattering

hence,

$$T_{fi} = 2\pi\delta(E_f - E_i) i(m/\eta)\overline{u}_f u_i \times$$
$$\times(-1/q_k q_k)(\rho(\mathbf{q})/\eta).$$

From the scattering amplitude shown above, the covariant amplitude is expressed as,

$$-iM^{(1)} = (im/\eta)\overline{u}_f u_i (i/q_k q_k)(i\rho(\mathbf{q})/\eta).$$

When the current of mass $\rho(x)$ is expressed as $\rho(x) = M\delta(x)$, the covariant amplitude is rewritten as,

$$-iM^{(1)} = (im/\eta)\overline{u}_f u_i (i/q_k q_k)(iM/\eta). \tag{9}$$

Therefore the potential V is calculated as,

$$V(r) = (2\pi)^{-3}(mM/\eta^2)\times$$
$$\times \int d^3q \ \exp(i\mathbf{q}\cdot\mathbf{r})(1/q_k q_k) = (4\pi r)^{-1}(mM/\eta^2).$$

It is expressed with SI units as,

$$V(r) = (4\pi r)^{-1}(mMc^4/\eta^2).$$

The force caused by that potential is thought to be equivalent to that of Newton's universal gravity, i.e.

$$(4\pi r)^{-1}(mMc^4/\eta^2) = \gamma(mM/r),$$

where γ is the gravitational constant ($= 6.673 \times 10^{-11} Nm^2Kg^{-2}$). From the above equation, we can calculate the actual value of η^2 as,

$$\eta^2 = c^4/(4\pi\gamma) = 9.634 \times 10^{42} N.$$

B) Gravitational Compton scattering

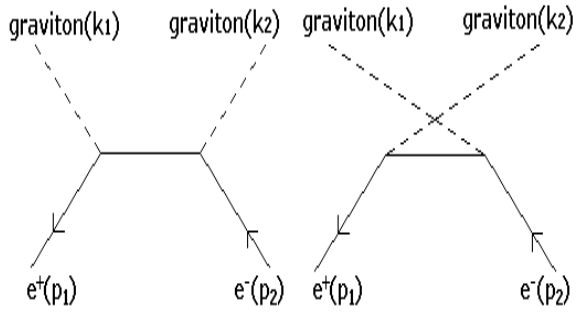

Figure 3: Feyman diagram for gravitational pair annihilation

The internal lines shown in the above figure are described with ordinary propagator of electron. Namely the covariant amplitude is expressed as,

$$\begin{aligned} -iM &= \overline{u}(p')(4k_0k_0')^{-1/2} \times \\ &\times[h(k')^*(im/\eta)(i(\gamma_\mu(p_\mu + k_\mu) + m)/ \\ &/((p+k)^2 - m^2))(im/\eta)h(k) + \\ &+h(k)(im/\eta)(i(\gamma_\mu(p_\mu - k'_\mu) + m)/ \\ &/((p-k')^2 - m^2))(im/\eta)h(k')^*]u(p), \end{aligned}$$

where h(k) is the Fourier transformation of h(x) appeared in the equation (8) used for expanding G.

C) Gravitational pair annihilation

The covariant amplitude is expressed as,

$$\begin{aligned} -iM &= \overline{v}(p_1)(4k_0k_0')^{-1/2} \times \\ &\times[h(k_1)^*(im/\eta)(i/(\gamma_\mu(p_{1\mu} - k'_{1\mu}) - \\ &-m))(im/\eta)h(k_2)^* + \\ &+h(k_2)^*(im/\eta)(i/(\gamma_\mu(p_{1\mu} - k'_{2\mu}) - \\ &-m))(im/\eta)h(k_1)^*)]u(p_2). \end{aligned}$$

As mentioned before, the gravitational interaction doesn't change the spin. Therefore if the sum of spin for electron and positron before the scattering is not null, the covariant amplitude shown above is null.

4. Difference between gravitational and electric interactions appeared on renormalization

The above examples show the gravitational and electric interactions are described with similar form in the first-order approximation except the change of spin. However in the second-order approximation, i.e. in the case considering the renormalization, there appears a significant difference between them. As the example, we consider the second-order approximation of gravitation-

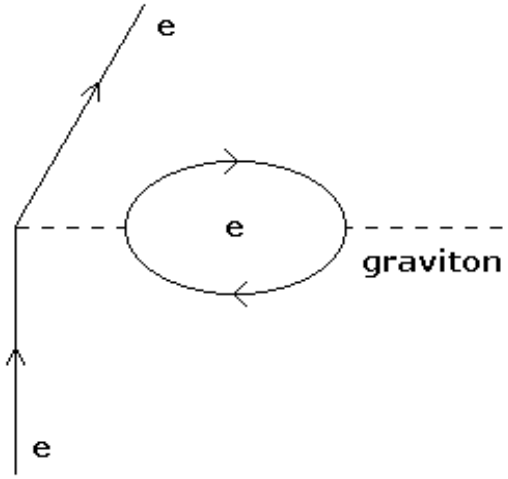

Figure 4: Feyman diagram for gravitational Rutherford scattering (2)

al Rutherford scattering shown in the following figure including a loop diagram.

Firstly we suppose the current of mass $\rho(x)$ as the external source is expressed as $\rho(x) = M\delta(x)$. Since the internal lines of electron are described with ordinary propagator of electron, the covariant amplitude in this case is expressed as,

$$-iM^{(2)} = (-1)(im/\eta)\overline{u}_f(-i/q^2)R(-i/q^2)(iM/\eta)u_i,$$

where

$$\begin{aligned} R &= \int d^4p\ (2\pi)^{-4}[(ie\gamma_\mu)_{\alpha\beta}(i(\gamma_\mu p_\mu + m)_{\beta\lambda}/ \\ &\quad /(p^2 - m^2))(ie\gamma_\mu)_{\lambda\tau} \times \\ &\quad \times(i(\gamma_\mu(p_\mu - q_\mu) + m)_{\tau\alpha}/((p-q)^2 - m^2))]. \end{aligned}$$

Although the integral R diverges, it is expressed with the similar way of the cut-off method on QED [2] as,

$$\begin{aligned} R = -ig_{\mu\mu}q^2[(e^2/(12\pi^2))ln(\Lambda^2/m^2) + \\ +(e^2/(60\pi^2))(q^2/m^2) + O(e^4)], \end{aligned}$$

where Λ is the cut-off constant. It should be noticed that $g_{\mu\mu} = -2$ and that summation changes the sign of integral and has never happened in the process of renormalization on QED. Thus the integral R is rewritten as,

$$\begin{aligned} R = 2iq^2[(e^2/(12\pi^2))ln(\Lambda^2/m^2) + \\ +(e^2/(60\pi^2))(q^2/m^2) + O(e^4)], \end{aligned}$$

therefore the sum of covariant amplitudes for the gravitational Rutherford scattering on the first-order approximation (9) and on the second-order approximation shown above is,

$$\begin{aligned} -iM &= -iM^{(1)} - iM^{(2)} = \\ &= (im/\eta)\overline{u}_f(-i/q^2)(iM/\eta)u_i \times \\ &\quad \times[1 + (e^2/(6\pi^2))ln(\Lambda^2/m^2) + \\ &\quad +(e^2/(30\pi^2))(q^2/m^2) + O(e^4)]. \end{aligned} \tag{10}$$

Renormalizing m, M, and e as,

$$\begin{aligned} m_R/m = M_R/M = e_R/e = \\ = [1 + (e^2/(6\pi^2))\ln(\Lambda^2/m^2)]^{1/2} \end{aligned} \tag{11}$$

the covariant amplitude (10) is rewritten as,

$$\begin{aligned} -iM = (im_R/\eta)\overline{u}_f(-i/q^2)(iM_R/\eta)u_i\times \\ \times[1 + ({e_R}^2/(30\pi^2))(q^2/{m_R}^2) + O(e^4)]. \end{aligned}$$

Therefore the corrected potential V is calculated as,

$$\begin{aligned} V(r) &= (2\pi)^{-3}(m_R M_R/\eta^2)\int d^3q\ \exp(i\mathbf{q}\cdot\mathbf{r}) \times \\ &\quad \times(1/q^2 + {e_R}^2/(30\pi^2 {m_R}^2)) = \\ &= (4\pi r)^{-1}(m_R M_R/\eta^2) + \\ &\quad +M_R {e_R}^2\delta(\mathbf{r})/(30\pi^2 m_R\eta^2). \end{aligned}$$

The above potential indicates an additional attractive force on electron due to the creation of virtual pair of electron-positron. Intuitively it is interpreted that the gravity caused by the external source creates the virtual pair of electron-positron and the mass of these virtual particles causes additional gravity. From the equation (11), it is shown that the greater the momentum, the smaller the running coupling constant as seen in QCD [3]. Namely the gravity mediated by G is thought to have the asymptotic freedom.

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TILTED BIANCHI TYPE I UNIVERSES FOR BAROTROPIC PERFECT FLUID IN GENERAL RELATIVITY

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In this paper, we have investigated that tilted Bianchi type I cosmological model for stiff perfect fluid under a supplementary condition $A = B^2$ between the metric potentials, is not possible. To preserve tilted nature of model, we consider dust fluid model of perfect fluid and a supplementary condition $A = B^{-\frac{1}{3}}$ between metric potentials is used. The physical and geometrical aspects of the models together with singularity in the models are also discussed.

1. Introduction

The Bianchi cosmologies play an important role in theoretical cosmology and have been much studied since the 1960s. A Bianchi cosmology represents a spatially homogeneous universe, since by definition the spacetime admits a three-parameter group of isometries whose orbits are spacelike hyper-surfaces. These models can be used to analyze aspects of the physical Universe which pertain to or which may be affected by anisotropy in the rate of expansion, for example , the cosmic microwave background radiation, nucleosynthesis in the early universe, and the question of the isotropization of the universe itself [1]. Spatially homogeneous cosmologies also play an important role in attempts to understand the structure and properties of the space of all cosmological solutions of Einstein field equations. A spatially homogeneous cosmology is said to be *tilted* if the fluid velocity vector is not orthogonal to the group orbits, otherwise the model is said to be *non-tilted* [2]. A tilted model is spatially homogeneous relative to observers whose world line are orthogonal relative to the group orbits, but is spatially inhomogeneous relative to observers comoving with the fluid. In a tilted Bianchi cosmology the tilt can become extreme in a finite time as measured along the fluid congruence, with the result that the group orbits become time-like. This means that the models are no longer spatially homogeneous [3].

The general dynamics of tilted models have been studied by King and Ellis [2], and Ellis and King [4]. Ellis and Baldwin [5] have shown that we are likely to be living in a tilted universe and they have indicated how we may detect it. Beesham [6] derived tilted Bianchi type V cosmological models in the scale-covariant theory. A tilted cold dark matter cosmological scenario has been discussed by Cen *et al.* [7]. Several researchers (Matravers *et al.* [8], Ftaclas and Cohen [9], Hewitt and Wainwright [10], Lidsey [11], Bali and Sharma [12], Hewitt *et al.* [13], Horwood *et al.* [14], Hewitt *et al.* [15], Bali and Meena [16], Barrow and Hervik [17], Apostolopoulos [18], Pradhan and Rai [19] and Hervik [20] have studied various aspects of tilted cosmological models.

The study of stiff fluid cosmological models is interesting in the sense that for such models the speed of light is equal to the speed of sound [21]. A realistic distribution of matter is a polytropic fluid inside a star. The Einstein's field equations require numerical method [22] for such a distribution and we use a semi-realistic equation of state $\rho = mp(n \geq 1)$. Ibanez and Sanz [23], Buchdahl and Land [24] and Whittaker [25] have obtained exact closed solutions for such a choice. Ibanez and Sanz [23] have investigated that these solutions are not general in special case of a stiff matter distribution. Hajj-Boutros [26] has investigated new exact solutions to the Einstein's equations which are spherically symmetric and static with stiff perfect fluid distribution of matter. Several researchers [27] – [31] have studied cosmological models with stiff perfect fluid distribution of matter in different context.

The cosmological models with heat flow have been studied by Coley and Tupper [32]; Roy and Banerjee [33]. Recently Bali and Meena [34] have investigated two tilted cosmological models filled with disordered radiation of perfect fluid and heat flow. Very recently tilted Bianchi type I cosmological model for perfect fluid distribution in presence of magnetic field is investigated by Bali and Sharma [16]. In this paper, we

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propose to find tilted Bianchi type I cosmological models filled with dust of perfect fluid in presence of a heat flow.

2. The Metric and Field Equations

We consider the Bianchi type I metric in the form

$$ds^2 = -dt^2 + A^2 dx^2 + B^2 dy^2 + C^2 dz^2, \tag{1}$$

where A, B and C are function of t only.
The Einstein's field equations are given by

$$R_i^j - \frac{1}{2} R g_i^j = -8\pi T_i^j \text{ (c = 1 = G in gravitational unit)}, \tag{2}$$

where R_i^j is the Ricci tensor; $R = g^{ij} R_{ij}$ is the Ricci scalar; and T_i^j is energy-momentum tensor for perfect fluid distribution with heat conduction given by Ellis [35] as

$$T_i^j = (\rho + p) v_i v^j + p g_i^j + q_i v^j + v_i q^j. \tag{3}$$

Here ρ and p are the energy density and isotropic pressure and v_i is the flow vector satisfying the relations

$$g_{ij} v^i v^j = -1, \tag{4}$$

$$q_i q^j > 0, \tag{5}$$

$$q_i v^i = 0, \tag{6}$$

where q_i is the heat conduction vector orthogonal to v_i.
The fluid flow vector has the component $(\frac{\sinh\lambda}{A}, 0, 0, \cosh\lambda)$ satisfying Eq. (4) and λ is the tilt angle.
The Einstein's field equations (2) for the line element (1) has been set up as

$$-8\pi \left[(\rho + p) \sinh^2 \lambda + p + 2q_1 \frac{\sinh\lambda}{A} \right] =$$

$$\frac{B_{44}}{B} + \frac{C_{44}}{C} + \frac{B_4 C_4}{BC}, \tag{7}$$

$$-8\pi p = \frac{A_{44}}{A} + \frac{C_{44}}{C} + \frac{A_4 C_4}{AC}, \tag{8}$$

$$-8\pi p = \frac{A_{44}}{A} + \frac{B_{44}}{B} + \frac{A_4 B_4}{AB}, \tag{9}$$

$$-8\pi \left[-(\rho + p) \cosh^2 \lambda + p - 2q_1 \frac{\sinh\lambda}{A} \right] =$$

$$\frac{A_4 B_4}{AB} + \frac{A_4 C_4}{AC} + \frac{B_4 C_4}{BC}, \tag{10}$$

$$(\rho + p) A \sinh\lambda \cosh\lambda + q_1 \cosh\lambda + q_1 \frac{\sinh^2\lambda}{\cosh\lambda} = 0, \tag{11}$$

where the suffix 4 at the symbols A, B, C denotes ordinary differentiation with respect to t.

3. Solution of the Field Equations and Their Physical Aspects

Equations (8) - (11) are five independent equations in seven unknowns A, B, C, ρ, p, q and λ. For the complete determinacy of the system, we need two extra conditions.
We first assume that the model is filled with stiff fluid of perfect fluid which leads to

$$\rho = p. \tag{12}$$

Secondly, we assume a supplementary condition between metric potentials as

$$A = B^2. \tag{13}$$

Eqs. (7) and (10) lead to

$$\frac{B_{44}}{B} + \frac{C_{44}}{C} + \frac{2B_4 C_4}{BC} + \frac{A_4 C_4}{AC} + \frac{A_4 B_4}{AB} = 8\pi(\rho - p). \tag{14}$$

Using eqs. (12) and (13) in (14), we have

$$(BC)_4 = k_1 B^{-2}, \tag{15}$$

where k_1 is a constant of integration. Equations (8) and (9) lead to

$$C^2 \left(\frac{B}{C} \right)_4 = \frac{k_2}{k_1} (BC)_4, \tag{16}$$

where k_2 is an integrating constant. Using $BC = \mu$ and $\frac{B}{C} = \nu$ in (16), we obtain

$$\frac{\nu_4}{\nu} = \frac{k_2 \mu_4}{k_1 \mu},$$

which on integration leads to

$$\nu = k \mu^{k_2/k_1}, \tag{17}$$

where k is an integrating constant. From eq. (15) we obtain

$$\mu_4 = k_1 (\mu\nu)^{-1}. \tag{18}$$

From eqs. (19) and (20), we obtain

$$\mu = (\alpha t + \beta)^K, \tag{19}$$

where

$$\alpha = \frac{2k_1 + k_2}{k}, \tag{20}$$

$$\beta = \frac{(2k_1 + k_2) k_3}{k_1}, \tag{21}$$

$$K = \frac{k_1}{2k_1 + k_2}, \tag{22}$$

where k_3 is constant of integration. Using (21) in (19), we obtain

$$\nu = k (\alpha t + \beta)^{\frac{k_2}{2k_1 + k_2}}. \tag{23}$$

Hence we have

$$A = k(\alpha t + \beta)^{\left(\frac{k_1+k_2}{k_1}\right)K}, \tag{24}$$

$$B = k^{1/2}(\alpha t + \beta)^{\left(\frac{k_1+k_2}{2k_1}\right)K}, \tag{25}$$

$$C = k^{-1/2}(\alpha t + \beta)^{\left(\frac{k_1-k_2}{2k_1}\right)K}. \tag{26}$$

After suitable transformation of coordinates, the metric (1) reduces to the form

$$ds^2 = 2\left(1 + \frac{k_2}{k_1}\right) K dX^2 + T^{\left(1+\frac{k_2}{k_1}\right)K} dY^2 +$$

$$T^{\left(1-\frac{k_2}{k_1}\right)K} dZ^2 - \alpha^{-2} dT^2. \tag{27}$$

The pressure and density of the model (29) are given by

$$p = \rho = \frac{(k_1 + k_2)(5k_1 - k_2)\alpha^2}{32\pi(2k_1 + k_2)^2 T^2}. \tag{28}$$

The reality conditions (i) $\rho + p > 0$ and (ii) $\rho + 3p > 0$ given by Ellis [29] are satisfied when $k_1 > k_2$. When $T \to \infty$, $\rho \to 0$, $p \to 0$. From Eqs. (11) and (12), we obtain

$$q_1 = -\frac{2pA \sinh\lambda \cosh^2\lambda}{\cosh 2\lambda}. \tag{29}$$

From eqs. (10) and (31), we have

$$\cosh 2\lambda = \frac{8\pi p}{\frac{A_4B_4}{AB} + \frac{A_4C_4}{AC} + \frac{B_4C_4}{BC}}. \tag{30}$$

Eq. (8) leads to

$$32\pi p = \frac{(k_1 + k_2)(5k_1 - k_2)\alpha^2}{(2k_1 + k_2)^2 T^2}. \tag{31}$$

Now we have

$$\frac{A_4B_4}{AB} + \frac{A_4C_4}{AC} + \frac{B_4C_4}{BC} = \frac{(k_1 + k_2)(5k_1 - k_2)\alpha^2}{4(2k_1 + k_2)^2 T^2}. \tag{32}$$

Using (33) and (34) in (32), we obtain

$$\cosh 2\lambda = 1,$$

which leads to

$$\cosh\lambda = 1,$$

i.e. $\lambda = 0$. Thus the model reduces to non-tilted one. The scalar of expansion θ calculated for the flow vector v_i, is given by

$$\theta = \frac{\partial \cosh\lambda}{\partial t} + \cosh\lambda\left(\frac{A_4}{A} + \frac{B_4}{B} + \frac{C_4}{C}\right),$$

which leads to

$$\theta = \frac{2k_1 + k_2}{kT}. \tag{33}$$

The non-vanishing components of shear tensor (σ_{ij}) are given by

$$\sigma_{11} = \frac{(k_1 + 2k_2)}{3k} T^{-\frac{k_1}{2k_1+k_2}}, \tag{34}$$

$$\sigma_{22} = -\frac{(k_1 - k_2)}{6k} T^{-\frac{k_1}{2k_1+k_2}}, \tag{35}$$

$$\sigma_{33} = -\frac{(k_1 + 5k_2)}{6k} T^{-\left(\frac{k_1+2k_2}{2k_1+k_2}\right)}. \tag{36}$$

The rotation in the model is identically zero.
The model (29), in general, represents a shearing and non-rotating universe. The universe reduces to non-tilted cosmological model in this case. The model starts with a big bang at $T = 0$ and the expansion in the model decreases as time increases and the expansion in the model also stops at $T = \infty$. The model has a singularity of Cigar type (MacCallum [36]) at $T = 0$ if $k_2 > k_1$. Since $\lim_{T\to\infty} \frac{\sigma}{\theta} \neq 0$, hence the model does not approach isotropy for large values of T.

4. Other Solution of the Field Equations and Their Physical Aspects

In this section we find the other type of solution of the field equations such that tilted nature of the model is preserved. For this we assume the model is filled with dust of perfect fluid which leads to

$$p = 0. \tag{37}$$

We also assume that

$$A = (B)^{-\frac{1}{3}} \tag{38}$$

Using Eq. (39) in (9), we get

$$\frac{A_{44}}{A} + \frac{B_{44}}{B} + \frac{A_4B_4}{AB} = 0. \tag{39}$$

Using Eq. (40) in (41) reduces to

$$6\frac{B_{44}}{B} + \frac{B_4}{B} = 0, \tag{40}$$

which on integration yields to

$$B_4 = \left(\frac{K_1}{B}\right)^{1/6}, \tag{41}$$

which again leads to

$$B = (\alpha t + K_2)^{6/7}, \tag{42}$$

where K_1 and K_2 are constants of integration and $\alpha = \frac{7}{6}K_1^{1/6}$.

$$Thus A = (\alpha t + K_2)^{-2/7}. \tag{43}$$

Using Eqs. (39) and (45) in (8), we obtain

$$(\alpha t+K_2)^2 C_{44}-\frac{2}{7}\alpha(\alpha t+K_2)C_4=-\frac{1}{2}K_1^{1/3}C. \quad (44)$$

Substituting $(\alpha t+K_2)\frac{dC}{dt}=\frac{dC}{d\tau}$ in (46), we have

$$\frac{d^2C}{d\tau^2}-\frac{9\alpha}{7}\frac{dC}{d\tau}=-\frac{1}{2}K_1^{1/3}C, \quad (45)$$

which on integration reduces to

$$C=K_3\left[(\alpha t+K_2)^{3/14}-K_4(\alpha t+K_2)^{-3/14}\right]\times$$

$$(\alpha t+K_2)^{9/14}, \quad (46)$$

where K_3 and K_4 are constants of integration. Therefore, after suitable transformation of coordinates, the metric (1) reduces to

$$ds^2=-\frac{dT^2}{\alpha^2}+T^{-4/7}dX^2+T^{12/7}dY^2+$$

$$K_3^2\left(T^{3/14}-K_4T^{-3/14}\right)T^{5/14}dZ^2. \quad (47)$$

The density of the model (49) is given by

$$\rho=\frac{9\alpha^2}{98\pi}\frac{1}{T^2}\left[\frac{T^{5/14}}{T^{3/14}-K_4T^{-3/14}}\right]. \quad (48)$$

The tilt angle λ is given by

$$\cosh\lambda=\sqrt{2}, \quad (49)$$

and

$$\sinh\lambda=1. \quad (50)$$

The expressions for fluid velocity v^i and heat conduction vector q^i for the model (49) are given by

$$v^1=T^{2/7}, \quad (51)$$

$$v^4=\sqrt{2}, \quad (52)$$

$$q_1=-\frac{K^{1/13}}{12\pi}\frac{1}{[T^{16/7}-K_4T^{13/7}]}, \quad (53)$$

$$q_2=\frac{1}{12\sqrt{2}\pi}\frac{1}{[T^2-K_4T^{11/7}]}. \quad (54)$$

The scalar of expansion θ, calculated for the flow vector v^i, is given by

$$\theta=\frac{\sqrt{2}K_1^{1/6}}{T}\left[\frac{17}{3}+\frac{(T^{3/7}+K_4)}{4(T^{3/7}-K_4)}\right]. \quad (55)$$

The non-vanishing components of shear tensor (σ_{ij}) and rotation tensor (ω_{ij}) are obtained as

$$\sigma_{11}=-\frac{11K_1^{1/6}}{27\sqrt{2}T^{7/9}}\left[\frac{29}{18}+\frac{T^{3/7}+K_4}{T^{3/7}-K_4}\right]; \quad (56)$$

$$\sigma_{22}=-\frac{11K_1^{1/6}}{9\sqrt{2}T^{7/9}}\left[\frac{19}{3}-\frac{T^{3/7}+K_4}{T^{3/7}-K_4}\right]; \quad (57)$$

$$\sigma_{33}=\frac{\sqrt{2}K_1^{1/6}K_3^2(T^{3/7}-K_4)^2}{27T^{76/63}}\left[\frac{5}{3}+\frac{T^{3/7}+K_4}{T^{3/7}-K_4}\right]; \quad (58)$$

$$\sigma_{44}=-\frac{7K_1^{1/3}}{36\sqrt{2}}\left[\frac{29}{3}+\frac{T^{3/7}+K_4}{T^{3/7}-K_4}\right]; \quad (59)$$

$$\sigma_{14}=-\frac{K_1^{1/6}}{6T^{7/9}}\left[\frac{35}{3}+\frac{T^{3/7}+K_4}{T^{3/7}-K_4}\right]; \quad (60)$$

$$\omega_{14}=2K_1^{1/6}T^{-9/6}; \quad (61)$$

The rate of expansion (H_i) in the direction of X, Y, Z-axes are given by

$$H_1=-\frac{K^{1/6}}{3T}; \quad (62)$$

$$H_2=\frac{K_1^{1/6}}{T}; \quad (63)$$

$$H_3=\frac{K_1^{1/6}}{T^{4/7}(T^{3/7}-K_4)}. \quad (64)$$

The model in general represents shearing and rotating universe. The model starts with a big bang at $T=0$ and the expansion in the model decreases as time increases and the expansion in the model stops at $T=\infty$. Since $\lim_{T\to\infty}\frac{\sigma}{\theta}\neq 0$, hence the model does not approach isotropy for large values of T. The model has cigar type singularity [36] at $T=0$. When $T\to 0$, energy density $\rho\to\infty$. When $T\to\infty$, $\rho\to 0$.

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A STUDY OF KINETIC ENERGY TO CLARIFY THE ROLE OF γ IN THE TRANSFORMATION OF VARIABLES REPRESENTING PHYSICAL QUANTITIES

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In this paper, we show that hv and all expressions for energy which are equivalent to it represent kinetic energy rather than total energy. The object velocity, u, is found to be relativistically invariant, along with the frequency of an object's de Broglie wave. Using the mathematics of indeterminancy (a term coined by the author to describe the introduction of an exponential scale or phase factor), we are able to derive a form of γ which emphasizes the underlying physics of the Galilean Transformation (GAL), the Lorentz Transformation (LT), and the general Einstein-Lorentz Transformation (GLT), rather than the details of each particular transformation. By requiring symmetry between the transformation properties of kinematic and dynamic variables, we find a more general transformation (MGT). For the condition $V \geq c$, in our spacetime, the (MGT) continues to describe a unique correspondence between the coordinates of two inertial frames of reference. We conclude by explaining how the logical necessity for zero rest mass in special relativity can be reconciled with physical observations of nonzero rest mass. In this way, it is also possible to show that the mass of an object does not become infinite if it were to move at the speed of light. Future theories may increase our understanding by providing more general representations of Nature. The various theories may be distinguished by the corresponding values of γ, the indeterminate part of which arises as the solution of an ordinary differential equation.

1.0 Introduction

Expressing the energy of a material object in terms of its mass can be done in a variety of ways. One can, for instance, use the inertial mass, the inertial rest mass, or the gravitational mass. The inertial mass and the inertial rest mass are simply related in our spacetime by the Lorentz transformation. Here we will see that writing the energy in a variety of ways leads to an important insight.

By setting one expression for the de Broglie wavelength

$$\lambda = \frac{v}{\nu}, \tag{1}$$

equal to another

$$\lambda = \frac{h}{mu} \tag{2}$$

and rearranging, one arrives at

$$m = \frac{h\nu}{uv}. \tag{3}$$

From this follows three expressions for energy

$$muv = h\nu, \tag{4}$$

$$pv = h\nu, \tag{5}$$

$$\frac{hv}{\lambda} = h\nu, \tag{6}$$

another expression follows if we note

$$p = \frac{h}{\lambda} = \frac{h}{2\pi}\frac{2\pi}{\lambda} = \hbar k, \tag{7}$$

$$\hbar kv = h\nu, \tag{8}$$

The important insight which we gained is the understanding that (4), (5), (6) and (8) are all different ways of expressing the *kinetic* energy of an object, rather than its total energy. To see how this becomes evident, we need to understand something about group velocity and phase velocity of matter waves.

1.1 The Group Velocity and the Phase Velocity of Matter Waves

The dispersion relation of a wave specifies the relation between ω and k, where ω is the angular frequency of the wave, given by

$$\omega = 2\pi\nu \tag{9}$$

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and k is the magnitude of the wave vector, given by

$$k = \frac{2\pi}{\lambda}. \tag{10}$$

The group velocity at angular frequency ϖ, in general is found from the dispersion relation of a wave by use of the following expression

$$v_g(\varpi) \equiv \left(\frac{d\omega}{dk}\right)_{\varpi}. \tag{11}$$

This is the velocity of points of constant amplitude. The phase velocity is the velocity of points of constant phase angle. It is found from the dispersion relation of a wave by use of the following expression

$$v_p = \left(\frac{\omega}{k}\right). \tag{12}$$

Here we will follow the convention of representing the phase velocity using the letter v without a subscript.

More information about dispersion relations may be found in Chapter 12 of the book by Main. [1] We have already encountered the dispersion relation for matter waves as (1). One can also find in Main's book another form for the dispersion equation of a matter wave [2]

$$\omega = \frac{\hbar}{2m}k^2 + \frac{V}{\hbar}. \tag{13}$$

From (11) and (13) we find the group velocity

$$v_g = \frac{\hbar k}{m}. \tag{14}$$

The classical velocity of a particle is obtained from its kinetic energy [3]

$$T = (1/2)\, m_0 v_{classical}^2. \tag{15}$$

This yields

$$v_{classical} = \sqrt{\frac{2T}{m_0}} = \frac{\hbar k}{m_0}, where \frac{\sqrt{2m_0 T}}{\hbar} \equiv k. \tag{16}$$

Thus we see that the group velocity corresponds to the relativistic form of the classical velocity of a particle. Consistent with this fact, we will denote the group velocity as the particle velocity by the letter u.

From (12) and (13) we find the phase velocity, which we will denote by the letter v.

$$v = \frac{\hbar k}{2m}, \tag{17}$$

in which we have set $V = 0$, because we are discussing a free particle.

1.2 Why kinetic energy?

To demonstrate why all expressions for energy which are equivalent to hv represent kinetic energy rather than total energy, we begin with equation (4)

$$muv = h\nu. \tag{18}$$

Substituting (19) for v yields

$$h\nu = mu\left(\frac{\hbar k}{2m_0}\right) = mu\sqrt{\frac{T}{2m_0}}, \tag{19}$$

where we have used the definition for k found in (16) to obtain the last expression. Rearranging yields

$$h\nu = \sqrt{T\left(\frac{m^2u^2}{2m_0}\right)}. \tag{20}$$

If $T = hv$, then

$$\sqrt{h\nu} = \sqrt{\frac{m^2u^2}{2m_0}} \tag{21}$$

or

$$h\nu = \frac{\gamma m u^2}{2}. \tag{22}$$

Since $mu^2 = T$, if $hv = T$ we have

$$h\nu = \frac{\gamma h\nu}{2}. \tag{23}$$

So

$$\gamma = 2 \tag{24}$$

and from (32) and (28)

$$h\nu = \hbar k u = \sqrt{2m_0 T}\, u, \tag{25}$$

so that

$$(h\nu)^2 = 2m_0 T u^2 \tag{26}$$

or

$$T = \frac{(h\nu)^2}{2m_0 u^2}. \tag{27}$$

Since we assumed $T = hv$, consistency demands that

$$T = 2m_0 u^2 = \gamma m_0 u^2 = mu^2. \tag{28}$$

But this is just what has been shown elsewhere (K.O. Cottrell, unpublished, 2004). Thus, our assumption was correct and we can state

$$h\nu = T. \tag{29}$$

This means that (4), (5), (6) and (8) are expressions for the kinetic energy of a particle.

We will show in section 1.3 that when $\gamma = 0$, one arrives at a consistent definition for the relativistic kinetic energy. We point in section 1.6 that when $\gamma = 1/2$, we arrive at the result of relativistic invariance of the object velocity, u, consistent with the transformation property of the scalar product of two arbitrary four-vectors. Somehow, we need both values of γ to describe physical reality. The question of why γ takes on these two values in order to describe physical reality is explored in section 1.4.

1.3 Understanding kinetic energy

The reader may wonder why there is no factor of 1/2 on the right hand side of (30). Holladay [4] gives the expression for relativistic kinetic energy (expressed below in our notation)

$$T = \frac{m_0 u^2 \gamma^2}{(1+\gamma)}. \tag{30}$$

Setting this equal to the right hand side of our expression (30) yields

$$mu^2 = \frac{m_0 u^2 \gamma^2}{(1+\gamma)} \tag{31}$$

or

$$\frac{m}{m_0} = \frac{\gamma^2}{\gamma+1}. \tag{32}$$

Since

$$\frac{m}{m_0} = \gamma, \tag{33}$$

we have

$$\gamma^2 = \gamma(\gamma+1) = \gamma^2 + \gamma, \tag{34}$$

so that

$$\gamma = 0. \tag{35}$$

But result (37) is deceptive in its simplicity, as we will see in section 1.4.

1.4 The mathematics of indeterminacy

The Lorentz transformations of the Theory of Special Relativity, when expressed in a more general form as the general Einstein-Lorentz transformation equations, are found to describe indeterminate quantities. In this theory, the spectrum of possible values of the dynamical or kinematic quantities, say mass and energy, or space and time, respectively, are provided by the action of γ. To discover the origin of γ, we start by using the invariance of object velocity, u, to write

$$\frac{1}{2} m_0 u^2 = \frac{m_0 u^2 \gamma^2}{(\gamma+1)}, \tag{36}$$

where we have used the expression for relativistic kinetic energy given by Holladay [5]. This yields

$$\frac{1}{2} = \frac{\gamma^2}{(\gamma+1)}, \tag{37}$$

from which we find

$$\gamma^2 - \frac{1}{2}\gamma - \frac{1}{2} = 0. \tag{38}$$

Using the quadratic formula to solve this quadratic equation gives the following two roots

$$\gamma = 1, \gamma = -1. \tag{39}$$

These values of γ are required to insure *both* the relativistic invariance of the object velocity and the consistency of the definition of relativistic kinetic energy. The other necessary values of γ which we have already identified, namely $\gamma = 2$, $\gamma = 0$ and $\gamma = 1/2$ are simply linear combinations of the two roots in (41). As Rainville and Bedient point out, "Any linear combination of solutions of a linear homogeneous differential equation is also a solution." [6] This suggests that γ is a solution of a differential equation. We now try to find this equation. We will make use of the conservation of momentum, by considering the universe to be a self-contained or closed system. This allows us to write

$$\frac{dp}{dt} = 0, \tag{40}$$

$$\frac{d(mu)}{dt} = u\frac{dm}{dt} + m\frac{du}{dt} = 0, \tag{41}$$

$$u\frac{d(\gamma m_0)}{dt} + \gamma m_0 \frac{du}{dt} = 0, \tag{42}$$

$$m_0 u \frac{d\gamma}{dt} + \left(u\frac{dm_0}{dt}\right)\gamma + m_0 \frac{du}{dt}\gamma = 0. \tag{43}$$

Since the rest mass m_0 is constant, the central term in (45) equals zero. We can then factor out m_0, and we arrive at

$$u\frac{d\gamma}{dt} + \frac{du}{dt}\gamma = 0, or m_0 = 0. \tag{44}$$

The first equation is clearly a (first-order) linear, homogeneous differential equation.

This can be rewritten

$$\frac{1}{\gamma}\frac{d\gamma}{dt} = -\frac{1}{u}\frac{du}{dt}. \tag{45}$$

We obtain a solution for $\gamma\gamma$ as follows

$$\frac{1}{\gamma}d\gamma = -\frac{a}{u}dt, \tag{46}$$

$$ln\gamma = -\frac{at}{u} + c, \tag{47}$$

$$\gamma = e^c e^{-\frac{at}{u}}, \tag{48}$$

Replacing a t with V, we can further specify γ by assuming that at $t = 0$, $u = u_0$ then

$$e^c = \frac{1}{\sqrt{1 - \frac{u_0^2}{w_0^2}}}, \tag{49}$$

so that

$$\gamma = \frac{e^{-\frac{V?}{u}}}{\sqrt{1-\frac{u_0^2}{w_0^2}}}. \tag{50}$$

We can express (52) in terms of two arbitrary reference frames O and O' by letting

$$u_0 \to u, w_0 \to w, and u \to u, \tag{51}$$

which gives the form

$$\gamma = \frac{e^{-\frac{V?}{u}}}{\sqrt{1-\frac{u^2}{w^2}}}. \tag{52}$$

Because we used (51) to find γ, (54) applies only to dynamical quantities such as mass and energy, so we will designate it accordingly as

$$\gamma_{mass-energy} = \frac{e^{-\frac{V?}{u}}}{\sqrt{1-\frac{u^2}{w^2}}} \tag{53}$$

and

$$m = m_0\gamma_{mass-energy} = \frac{m_0 e^{-\frac{V?}{u}}}{\sqrt{1-\frac{u^2}{w^2}}}. \tag{54}$$

To find the corresponding expresion for γ for use with kinematic quantities, we note that (51) becomes

$$e^c = \frac{(1-\beta_0)}{\sqrt{1-\beta_0^2}} = \frac{\left(1 - \frac{V}{w_0}\right)}{\sqrt{1 - \frac{V^2}{w_0^2}}}, \tag{55}$$

so that the kinematic expression for γ becomes, after the appropriate transformation (37)

$$\gamma_{space-time} = \frac{e^{-\frac{V}{u}}\left(1 - \frac{V}{w}\right)}{\sqrt{1 - \frac{V^2}{w^2}}} \tag{56}$$

and

$$t = t\gamma_{space-time} = \frac{e^{-\frac{V}{u}}\left(1 - \frac{V}{w}\right)t}{\sqrt{1 - \frac{V^2}{w^2}}}, \tag{57}$$

$$x = x\gamma_{space-time} = \frac{e^{-\frac{V}{u}}\left(1 - \frac{V}{w}\right)x}{\sqrt{1 - \frac{V^2}{w^2}}}. \tag{58}$$

We now describe some specific cases of how the mathematics of indeterminancy reveals the underlying transformation principle, rather than a specific tranformation rule, when examined within the domains of established theories. In the discussion below we will use the following abbreviations: Galilean Transformation (GAL), Lorentz Transformation (LT),and general Einstein-Lorentz Transformation (GLT).

Case 1. (GAL).

In this case

$$u' = u - V, u = 0, V = 0,$$

$$\gamma_{mass-energy} = indeterminate,$$

$$\gamma_{space-time} = indeterminate,$$

$$\beta = indeterminate.$$

This represents the transformation of the description of a stationary object between two coordinate systems which are at rest with respect to each other.

Case 2. (GAL).

In this case

$$u' = u - V, u \neq 0, V = 0,$$

$$\gamma_{mass-energy} = \infty,$$

$$\gamma_{space-time} = \pm 1,$$

$$\beta = 0.$$

This represents the transformation of the description of a moving object between two frames of reference which are stationary with respect to each other.

Case 3. (GAL).

In this case

$$u' = u - V, u \neq 0, V \neq 0,$$

$$\gamma_{mass-energy} = \infty,$$

$$\gamma_{space-time} = \pm 1,$$

$$\beta = 0.$$

This represents the transformation of the description of a moving object between two frames of reference which are moving with respect to each other with relative velocity V.

Case 4. (LT).

In this case

$$u' = u = c, V = 0,$$

$$\gamma_{mass-energy} = \infty,$$

$$\gamma_{space-time} = \pm 1,$$

$$\beta = 0.$$

This represents the transformation of the description of an object between two coordinate systems which are at rest with respect to each other.

Case 5. (LT).

In this case

$$u' = u = c, |V| < c,$$

$$\gamma_{mass-energy} = \infty,$$

$$\gamma_{space-time} = \frac{e^{-\beta}(1-\beta)}{\sqrt{1-\beta^2}},$$

$$\beta = \frac{V}{c}.$$

This represents the transformation of the description of an object between two coordinate systems which are moving with respect to each other with relative velocity $-c < V < c$.

Case 6. (LT).

In this case

$$u' = u = c, V = c,$$

$$\gamma_{mass-energy} = \infty,$$

$$\gamma_{space-time} \propto \frac{1}{e},$$

$$\beta = 1.$$

This represents the transformation of the description of an object between two frames of reference which are moving with respect to each other with velocity $V = c$.

Case 7. (GLT).

In this case

$$u' = u = w = 0, V = 0, u' = u = w \neq 0, V = 0,$$

$$\gamma_{mass-energy} = indeterminate, \gamma_{mass-energy} = \infty,$$

$$\gamma_{space-time} = indeterminate, \gamma_{space-time} = \pm 1,$$

$$\beta = indeterminate, \beta = 0.$$

This represents the transformation of the description of an object between two coordinate systems which are at rest with respect to each other.

Case 8. (GLT).

In this case

$$u' = u = w, |V| < w,$$

$$\gamma_{mass-energy} = \infty,$$

$$\gamma_{space-time} = \frac{e^{-\beta}(1-\beta)}{\sqrt{1-\beta^2}},$$

$$\beta = \frac{V}{w}.$$

This represent the transformation of the description of a moving object between two coordinate system which are at moving with respect to each other with $-w \leq V \leq w$.

Case 9. (GLT).

In this case

$$u' = u = w, V = w,$$

$$\gamma_{mass-energy} = \infty,$$

$$\gamma_{space-time} \propto \frac{1}{e},$$

$$\beta = 1,$$

This represents the transformation of the description of an object between two coordinate systems which are moving with respect to each other with relative velocity $V = w$.

We see from a study of the cases outlined above that when β is the same, the underlying physics is the same. Note that in all cases where β is not indeterminate, the value of $\gamma_{mass-energy}$ is infinite. This should not be surprising, because $\gamma_{mass-energy} = \infty$ serves to define an inertial frame of reference, according to Newton's First Law. Since we are always dealing with inertial frames here, this applies to all every case. When $\beta = 0$, $\gamma_{space-time} = \pm 1$. This describes the property of invariance with respect to translations in space and translations in time. This corresponds to the principles of momentum conservation and energy conservation, respectively. Case 5 and case 8 describe more general situations in which the momentum and energy are conserved only when the relative velocity, $V = 0$. Case 8 embodies (GAL) in the sense that there is no single finite limiting velocity, but it also embodies (LT) in the sense that there does exist a finite limit, though unspecified. When $\beta = 1$, we see that $\gamma_{space-time} = 1/e$, and describes exponential decay.

Thus, we see that (GAL) and (LT) correspond to special cases of (GLT), and that the consequences of these three transformations can be expressed in a general way that reveals their underlying physical principles, by using the mathematics of indeterminacy. We also see when we do this that exponential growth and decay can be viewed as a process of repeated coordinate transformations.

1.5 Using γ to unite the transformations of kinematic and dynamic physical quantities

Since we are examining energy in this paper, it is appropriate to point out the fact that the Einstein equation and the Planck-Einstein equation are two *fundamentally different representations* of the energy of an object. The Einstein equation represents a kinematic quantity, while the Planck-Einstein equation represents a dynamic quantity. For the reader who is unfamiliar with this terminology, kinematics is "motion without regard to the forces that may accompany it," while dynamics is "the study of how motion changes." [8] One can set the right hand sides of these equations equal to each other by associating $\gamma_{space-time}$ with the kinematic quantity and $\gamma_{mass-energy}$ with the dynamic quantity. This gives

$$\frac{h\nu_0\left(1-\frac{V}{w}\right)e^{-\frac{V}{u}}}{w^2\sqrt{1-\frac{V^2}{w^2}}}=\frac{m_0e^{-\frac{V}{u}}}{\sqrt{1-\frac{u^2}{w^2}}}. \tag{59}$$

This may be rearranged to give

$$\left[\frac{h\nu_0\left(1-\frac{V}{w}\right)\sqrt{1-\frac{u^2}{w^2}}-m_0w^2\sqrt{1-\frac{V^2}{w^2}}}{w^2\sqrt{1-\frac{V^2}{w^2}}\sqrt{1-\frac{u^2}{w^2}}}\right]\cdot$$

$$\cdot e^{-\frac{V}{u'}}=0. \tag{60}$$

As before, we find it useful to consider particular cases. When $u=u'\neq 0$, $V=0$, $0<u<c$, one finds

$$\frac{h\nu_0\sqrt{1-\frac{u^2}{w^2}}-m_0w^2}{w^2\sqrt{1-\frac{u^2}{w^2}}}=0 \tag{61}$$

and when $u=0$, $u'=-V$, $|V|\leq w$, one finds

$$\left[\frac{h\nu_0\left(1+\frac{u'}{w}\right)-m_0w^2\sqrt{1+\frac{u'V}{w^2}}}{w^2\sqrt{1+\frac{u'V}{w^2}}}\right]e=0. \tag{62}$$

From (63) one finds

$$\frac{h\nu_0}{m_0w^2}=\frac{1}{\sqrt{1-\frac{u^2}{w^2}}}. \tag{63}$$

This result corresponds to the (GLT) case of $\gamma_{mass-energy}$. Since both m_0 and $h\nu_0/w^2$ represent mass, but are not in general equal to each other, we see that when using mass as a descriptive quantity we must distinguish between kinematic mass ($h\nu_0/w^2$) and dynamic mass (m_0). It is thus better to speak in terms of energy since there is just one kinetic energy. From (64) one finds

$$\frac{h\nu_0}{m_0w^2}=\frac{\sqrt{1+\frac{u'V}{w^2}}}{\left(1+\frac{u'}{w}\right)} \tag{64}$$

This result defines a new γ whose transformation properties are physically equivalent to those of $\gamma_{mass-energy}$. We can find a general form for this new γ by using the principles of the mathematics of indeterminacy, i.e., returning to the general solution of our differential equation for γ. When we do this, we find

$$e^c=\frac{\sqrt{1+\frac{uV}{w^2}}}{\left(1+\frac{u}{w}\right)}, \tag{65}$$

so that

$$\gamma=\frac{\sqrt{1+\frac{uV}{w^2}}}{\left(1+\frac{u}{w}\right)}e^{-\frac{V}{u'}}. \tag{66}$$

Expression (68) is an expression for γ which can now be used with to transform *both* kinematic and dynamic quantities. Thus the full set of transformation equations connecting the descriptions of both kinematic and dynamic quantities in two frames of reference which are moving with respect to each other with relative velocity, V and corresponding to a more general transformation (MGT) than that given by the general Einstein-Lorentz Transformation equations (GLT) may be written as follows:

$$m=\gamma m_0=\frac{\sqrt{1+\frac{uV}{w^2}}}{\left(1+\frac{u}{w}\right)}2m_ae^{-\frac{V}{u'}}, \tag{67}$$

$$t'=\gamma t=\frac{\sqrt{1+\frac{uV}{w^2}}}{\left(1+\frac{u}{w}\right)}te^{-\frac{V}{u'}}, \tag{68}$$

$$x'=\gamma x=\frac{\sqrt{1+\frac{uV}{w^2}}}{\left(1+\frac{u}{w}\right)}xe^{-\frac{V}{u'}}, \tag{69}$$

$$h\nu_0=\gamma\left(m_0w^2\right)=\frac{w^2\sqrt{1+\frac{uV}{w^2}}}{\left(1+\frac{u}{w}\right)}2m_ae^{-\frac{V}{u'}}, \tag{70}$$

or in 4-vector notation

$$(m,t',x',h\nu)=\gamma\left(m_0,t.x,h\nu_0\right). \tag{71}$$

The definition of m_a is given in section 2.6. Note that in the transformation equations expressed by (69)-(72), the relative velocity V can exceed the speed of light, even in our spacetime (i.e., with $u=u'=w=c$).

1.6 Why this is important

The relativistic energy, E, of a particle moving in a general spacetime manifold includes the rest mass energy and is given by

$$E = mw^2 = T + m_0 w^2. \tag{72}$$

From (4) and (24) it now follows, after some rearrangement

$$mw^2 - muv = m_0 w^2. \tag{73}$$

Factoring out the m on the left and dividing both sides by the factored quantity yields

$$m = \frac{m_0 w^2}{w^2 - uv}. \tag{74}$$

The following expression may be used to define the velocity of the wavefront of matter waves

$$w = \sqrt{uv}. \tag{75}$$

Further, the following condition must be met in order to obtain a correct physical description from an analysis which treats particles as matter waves

$$w = c. \tag{76}$$

From the denominator of (76) it is evident that, with $w = c$, one is forced to conclude that the rest mass of a particle is zero if inertial mass is to be a definable quantity. This is apparently true, in general, even for objects which maintain a constant velocity $0 < u \neq c$, with $w = u$.

The fact that the rest mass of a particle which is moving at the speed of light is zero is typically presented as an ad hoc postulate. See, for example, the introduction to this paper. [9] Nevertheless, it has long been accepted because it makes sense. Stated another way, a measurement of the mass of an object by an observer who is at rest in a frame of reference which is moving with velocity $V = c$ with respect to a frame containing the object at rest, made with respect to the frame of the object, is found to be zero. Now (76) shows the truth of this assertion.

What equation (76) also tells us is that, in general, if the observer is at rest in a frame of reference which is moving at a velocity $V = u_0$ which is greater than zero, and even though not equal to the speed of light, such an observer will still measure the mass of an object in its rest frame to be zero. In other words, there is no constant velocity of motion u_0, with $0 < u_0$, such that an object which moves at $u = u_0$ can have a rest mass $m_0 > 0$. This is an important statement, because all objects which can be represented by an inertial frame of reference can be described as objects which move at $u = u_0$. Thus, all object must have a zero rest mass, including those for which $u = 0$. Any object which moves with constant velocity $u = u_0 \geq 0$ must have a zero rest mass. It has been pointed out that in our spacetime the instantaneous measurement of a component of the velocity of an electron always yields $u = \pm c$ [10]. In this case it is already clear that the rest mass of the object as understood by the principles of special relativity must equal zero.

To see how zero rest mass makes sense with our current understanding of nature, we must return to what we have learned in the previous section about the mathematics of indeterminacy. From (52 – 53) we see that when one speaks about an apparent mass, i.e.., one which is defined by an indeterminate mathematical expression, one really means

$$m = \frac{m_0}{\sqrt{1 - \frac{u^2}{w^2}}} e^{-\frac{V}{u'}}. \tag{77}$$

When $w = u = c = u'$ and $m_0 = 0$, we have

$$m = (Constant)\, e^{-\frac{V}{c}}. \tag{78}$$

We can simplify this further by assuming that when $V = 0$, the value of m is proportional to an experimentally determined constant m_a. Then

$$m \propto m_a e^{-\frac{V}{c}}, \tag{79}$$

where the constant m_a is the "apparent" or "actual" (i.e., experimentally determined) rest mass of the object and in contrast to the number we theoretically associate with rest mass, and which we currently call by convention m_0. When $V = c$, the mass of an object is given by

$$m \propto m_a e^{-1}. \tag{80}$$

Thus, the mass of an object does not become infinite when $V \to c$, so that one cannot use the idea of an unbounded relativistic mass increase to explain why it is not possible to travel faster than the speed of light. There does not seem to be any physical limitation preventing faster than light travel, rather the apparent limitation is a consequence of the manner in which we currently use transformation equations to describe changes in dynamic and kinematic quantities as a result of coordinate transformation. It is conceivable that in the future we will learn to express the essential transformation equations in a way which avoids the inherent limitations found in those that we use today. This will allow us to *understand* that it is possible to travel faster than the speed of light so that we can begin to develop the technology that will make interstellar travel a reality. As a first step in this direction, consider the (MGT) transformation equation for mass.

$$m = \gamma m_0 = \frac{\sqrt{1 + \frac{uV}{w^2}}}{(1 + \frac{u}{w})} m_0 e^{-\frac{V}{u'}}. \tag{81}$$

When $V \to c$, with $(u = u' = w = c)$ defining our spacetime manifold, we find

$$m = \frac{\sqrt{2}}{2} m_0 e^{-1} \tag{82}$$

and when $V \to 0$, with $(u = u' = w = c)$ defining our spacetime manifold, we find

$$m = \frac{1}{2} m_0 = m_a, \tag{83}$$

so that when $V \to c$,

$$m = \sqrt{2} m_a e^{-1}. \tag{84}$$

1.7 The invariance of object velocity and de Broglie frequency

As a final note, we point out that with the work of section 2.2 we have shown that when $\gamma = 1/2$ one finds

$$T = mu^2 = \frac{1}{2} m_0 u^2, \tag{85}$$

which is a statement that the velocity, u, of an object is relativistically invariant. This corresponds to the property, pointed out by Field, that the scalar product of two arbitrary four-vectors, $\mathbf{C}$, $\mathbf{D}$ given by $\mathbf{C} \cdot \mathbf{D}$ is manifestly Lorentz invariant. [11] There is an additional result related to the invariance of the velocity of an object. From (4) and (31) and the property of invariance, we have

$$T = mu'v' = h\nu, \tag{86}$$

this may be rewritten

$$\frac{hv}{\lambda} = mu'v', \tag{87}$$

or

$$\frac{h}{mu'v'} = \frac{\lambda}{v}. \tag{88}$$

Thus

$$\frac{\lambda'}{v'} = \frac{\lambda}{v}, \tag{89}$$

from which

$$\frac{1}{\nu'} = \frac{1}{\nu}, \tag{90}$$

or

$$\nu' = \nu. \tag{91}$$

So the frequency of an object's de Broglie wave is relativistically invariant.

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FIELD THEORY FICTIONS AND GHOSTS

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Absolutistic viewpoints on homopolar electrodynamics deserve to be thoroughly revisited under the light of recent relevant experimental evidences on the generalized prevalence of Newton's Third Law.

Some misconceptions on electromagnetic induction by a previous European Journal of Physics article by H. Montgomery [1] are pointed out in a recent publication by J. Guala-Valverde [2]. While the analysis correctly sets the prevalence of relative over absolute motion in the phenomenon, it dismisses previously exposed angular momentum conservation considerations [3]. In effect, Montgomery wrote "This paradox illustrates the point that one has to be extremely careful when one applies Newton's third law to electromagnetic systems. The electromagnetic field itself possesses momentum, a concept which is more familiar to most of us in the case of photons than it is for static fields. The density of linear momentum is given by Poynting's vector, divided by $c^2, g = \left(1/c^2\right) E \times H$".

Indisputable experimentation [4, 5, 6, 7, 8, 9] definitively disproves any speculation on electromagnetic field momentum conservation for the homopolar motor case. Let us consider the simplest unipolar motor arrangement: a disk-shaped magnet, a radial probe free to rotate around the magnet axis, and a closing wire connecting the probe to a DC source. The probe and the closing wire, despite of having electric continuity, remain mechanically decoupled. With DC current injected in the circuit, Laplace forces arise from the magnetic field *simultaneously* pushing the probe and pulling the closing wire with equal but opposite torques. Newton's third law is hence fully validated [5, 6] and the chances to apply this valuable-for-radiation tool to static fields, vanishes.

Moreover, Poynting's vector calculations – extensively applied to electromagnetic radiation become senseless in static fields as already stressed by Graneau [10], Assis [11] and others. It is worthwhile to recall Assis' analysis of Deis *et al* experiments [12]. A *0.3 Kg* mass projectile was launched by a railgun -a linear homopolar motor- at a speed in the *4000 m/s* range acquiring a linear momentum of some *1300 Kgm/s*. Electromagnetic-field momentum conservation would, in this case, require an electromagnetic mass in the *4.0E-6 Kg* range. The equivalent energy for such hypothesis would be $E = mc^2 > 4.0E11 \cdot J$, a magnitude far in excess of the less than *2.0E7 J* energy released by the source during launching.

In conclusion, and considering the associated homopolar-induction physics fully elucidated, nonsensical calculations based on the existence of a hypothetic *field momentum* become untenable and should be abandoned. We cannot refrain ourselves from quoting Newton's First Rule of Reasoning: *"We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances"*, Principia.

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A REEXAMINATION OF THE ROLE OF REST MASS IN SPECIAL RELATIVITY

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The standard argument that a photon must have zero rest mass is usually accepted on faith. In this paper, a thought experiment is performed to reexamine the question of whether the rest mass of a photon is really zero. This experiment leads to the conclusion that the photon has zero rest mass. This is consistent with conventional expectations. However , the experiment also leads to the conclusion that the rest mass of an arbitrary object is also identically equal to zero. Clearly, this violates common sense, and requires further explanation. An outline of this explanation, based on the fact that mass is an apparent quantity (one which is expressed by an indeterminate mathematical expression) has already been presented, using the mathematics of indeterminacy. It is suggested here that the parameter β in the relativistic transformation equations defines a spacetime gauge of the type originally proposed by Weyl in 1918 that makes possible the constancy of the velocity of light. β is characteristic of a particular spacetime manifold, and its value for our spacetime is calculated. We use the value of β to extend the earlier explanation for observed nonzero rest mass of an arbitrary object by presenting the results of a calculation of the value of the experimentaly measurable rest mass and the inertial mass as a function of the de Broglie frequency. The electron is used as an example, and it becomes evident how an understanding of wave-particle duality can emerge from the symmetry between wave and particle properties which characterizes Nature when viewed through a model based on matter waves.

1.0 Introduction

In the field of physics, there are certain beliefs which have developed that are taught to each subsequent generation of physics students until they attain the status of dogma. One of these beliefs is that the rest mass of a photon is zero. The standard argument which is presented to demonstrate this fact runs something as follows. The expression for the inertial mass of a photon is given in special relativity theory as

$$m = \frac{m_0}{\sqrt{1 - \frac{u^2}{c^2}}}. \tag{1}$$

Since a photon has a velocity, u, which equals the speed of light, c, equation (1) becomes the following for a photon

$$m = \lim_{u \to c} \frac{m_0}{\sqrt{1 - \frac{u^2}{c^2}}} = \infty. \tag{2}$$

But infinite mass for a photon cannot correspond to physical reality. Mass is a measure of the inertia of an object. Inertia is the resistance of an object to a change in its state of motion. If a photon's inertia were infinite it would be impossible to stop a photon, for example, with a piece of film, and it would be impossible to image objects photographically, which we know is not the case. The only way to resolve this problem is if the rest mass, m_0, of a photon is equal to zero. If the rest mass is zero, then we have

$$m = \frac{0}{0} \to indeterminate. \tag{3}$$

An indeterminate quantity is one which can take on any value. For a photon, this would correspond to the *apparent* inertial mass found by setting Einstein's equation for the equivalence of mass and energy

$$E = mc^2, \tag{4}$$

equal to the Planck-Einstein equation for the energy of a photon

$$E = h\nu, \tag{5}$$

which yields

$$m = \frac{h\nu}{c^2}. \tag{6}$$

Physicists prefer to speak of a property of the photon which has been confirmed by measurements involving the collision of light with matter, namely its momentum, p. The momentum of an object is equal to its inertial mass times its velocity. For a photon we see that this is given by

$$p = mc = \frac{h\nu}{c}. \tag{7}$$

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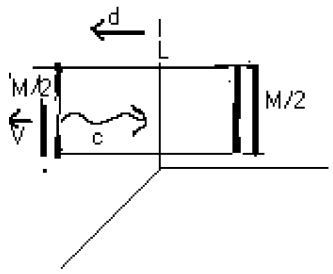

Figure 1: Photon emission at $x = -L/2$, at $t = 0$.

This definition remains true in general for an arbitrary object only if the rest mass energy can be considered kinetic in origin.

Equation (7) leads to the well known de Broglie equation

$$p = \frac{h}{\lambda}. \tag{8}$$

This equation plays an important role in the work presented in this paper. We begin by using it in the Prologue to investigate photon mass.

1.1 Do photons have mass? A thought experiment

Let us imagine the following thought experiment, the conceptual structure of which was first presented by Jeff Kern at the University of Vermont in 1998. Consider a box of length L to be centered along the x-axis in a rectangular coordinate system. The box has mass M_0, but most of the box is of negligible mass, except for the two ends of the box located at $x = -L/2$ and $x = L/2$. At time $t = 0$, a photon is emitted from the side of the box located at $x = -L/2$ and moves in the positive x-direction until it reaches the side of the box at $x = L/2$ at time t, where it is absorbed. During this process we require momentum to be conserved because no outside forces are acting on the system. What must the rest mass of the photon be?

Momentum conservation for the system is described by the following equation

$$p_{photon,initial} + p_{box,initial} = \\ = p_{photon,final} + p_{box,final}. \tag{9}$$

Initially, the momentum of the system is equal to zero, so the left side of equation (9) equals zero. Thus, we have

$$p_{box,final} = -p_{photon,final}. \tag{10}$$

The momentum of the emitted photon is given by

$$p_{photon} = \frac{h}{\lambda}, \tag{11}$$

where λ is the wavelength of the photon and h is Planck's constant. Thus the momentum of the box after emission of the photon is

$$MV = -\frac{h}{\lambda}, \tag{12}$$

where M is the mass of the moving box and V is the velocity of the box relative to an observer who is stationary in the coordinate system in which the box is represented.

The distance that the emitted photon moves in time t is given by

$$d_{foton} = ct \tag{13}$$

while the box move in the opposite direction an amount given by

$$d_{box} = -Vt \tag{14}$$

Solving (13) for V and substituting into (14) yields

$$d_{box} = \frac{ht}{\lambda M}. \tag{15}$$

When an amount of time has elapsed such that $d_{photon} + d_{box} = L$, the length of the box, the photon is absorbed at the opposite end of the box. This amount of time is given by

$$t|_{d_{photon}+d_{box}=L} = \frac{L}{c + \frac{h}{\lambda M}} = \frac{L\lambda M}{\lambda Mc + h}. \tag{16}$$

The distance which the center of mass (CM) of the box appears to move during this time is given by substituting (14) into (13) and simplifying

$$d_{box} = \frac{hL}{\lambda Mc + h}. \tag{17}$$

To find the mass of the emitted photon, we now ask how much mass we will have to move to get the same effect. For the distribution of mass created by emission of the photon it is true that

$$\left(\frac{M_0}{2} - m_0\right)\left(\frac{L}{2} + d_{box}\right) = \\ = \left(\frac{M_0}{2} + m_0\right)\left(\frac{L}{2} - d_{box}\right). \tag{18}$$

This can be simplified to yield the following relationship

$$m_0 = \frac{M_0 d_{box}}{L}. \tag{19}$$

By substituting (15) into (19) and simplifying we arrive at the following expression for m_0

$$m_0 = \frac{hM_0}{\lambda Mc + h}. \tag{20}$$

We can obtain an expression for M by recalling that $d_{photon} + d_{box} = L$. Since

$$L = ct + \frac{ht}{\lambda M}, \tag{21}$$

we have

$$\frac{L - ct}{\frac{ht}{\lambda}} = \frac{1}{M}, \tag{22}$$

so that

$$M = \frac{ht}{\lambda\,(L - ct)}. \tag{23}$$

We can now substitute expression (23) for M in expression (20) for m_0. This yields, after extensive simplification, the following expression for m_0

$$m_0 = M_0 \left(1 - \frac{ct}{L}\right). \tag{24}$$

Equation (24) tells us that when $L = ct$, $m_0 = 0$. This means that the breakdown of Galilean relativity implies a zero rest mass for the photon, because if $L = ct$, the photon is oblivious to the relative motion of the box with respect to the coordinate system, consistent with the results of Einstein's theory of special relativity for an object moving at the speed of light. If the rest mass of the photon is not zero, it must have some finite, minimum value. Substituting equation (21) for L into (24) we find

$$m_0 = M_0 \left(1 - \frac{c}{c + \frac{h}{\lambda M}}\right). \tag{25}$$

Thus, a minimum value for m_0 corresponds to a maximum value of lambda, the wavelength of the photon. The maximum wavelength of the photon is given by the following equation

$$\lambda = \frac{c}{\nu_1}, \tag{26}$$

so that a maximum value for lambda is seen to correspond to a minimum value for the frequency of the photon, v_1. A longer wavelength photon will require a greater amount of time to be absorbed, by a factor proportional to $lambda/c$ so that we see the time, t, in equation (21) corresponds to $1/v_1$ [1]. A concrete model may serve to make this more clear.

The essential process involved here is the emission and absorption of a photon. We could have chosen to model this process a different way, and here a secondary model proves useful. Consider an electron moving in a circular orbit. At some point P in its orbit the electron emits a photon. Because the photon is moving faster than the electron, it will circle around and overtake the electron at point P', catching up in a distance equal to one complete orbit plus the distance from P to P'. The net displacement of the photon is thus equal to the distance from P to P'. If the time required for the photon to travel this distance is t, then vt is the number of cycles (or vibrations) which an external observer counts as the photon moves from P to P'. Because the photon is emitted at P and absorbed at P', the number of cycles must be an integer: i.e., $vt = n$, where $n = 1, 2, 3, \ldots N$. A minimum value of frequency $v = v_1$ corresponds to the minimum value for n, namely, $n = 1$. Thus, $t = 1/v_1$.

Making this substitution, and simplifying with the help of (26) yields the following result

$$L = \frac{h}{Mc} + \lambda_{max}. \tag{27}$$

Our task is to use the de Broglie equation to find an expression for L. We begin by using (7) and (8) to write

$$u = \frac{h\nu}{mv} = \frac{h}{m\lambda_{max}}. \tag{28}$$

Using (1) we may write

$$u = \frac{h}{\frac{m_0}{\sqrt{1 - \frac{u^2}{c^2}}}\lambda_{max}}, \tag{29}$$

so that

$$\lambda_{max} = \frac{h\sqrt{c^2 - u^2}}{m_0 uc}. \tag{30}$$

Thus (21) can be rewritten

$$L = \frac{h}{c}\left(\frac{M\sqrt{c^2 - u^2} + m_0 u}{m_0 uM}\right). \tag{31}$$

If we now return to equation (24) and substitute (31) for L and replace t with $1/v_1$ we arrive at the following expression

$$m_0 = M_0 \left(1 - \frac{c^2}{h\nu_1}\left(\frac{m_0 uM}{M\sqrt{c^2 - u^2} + m_0 u}\right)\right). \tag{32}$$

Since $u = c$ for a photon,

$$m_0 = M_0 \left(1 - \frac{Mc^2}{h\nu_1}\right). \tag{33}$$

But the energy of a photon, measured with respect to an external observer is given by

$$E_0 = h\nu_0 = m_0 c^2. \tag{34}$$

Since v_1 is the minimum value of frequency, v_0 must equal v_1 This yields the following result

$$\frac{m_0}{M_0} = 1 - \frac{M}{m_0}. \tag{35}$$

If one solves for m_0 one finds

$$m_0 = \pm\sqrt{(m_0 - M)\, M_0}. \tag{36}$$

Since mass must be positive, we examine only the positive root. From the physical arrangement of the problem, M must be greater than m_0. Since mass must be a real quantity, this leads directly to the conclusion that *the photon has zero rest mass, and the rest mass of an arbitrary object is also identically equal to zero*

$$m_0 = M_0 = 0. \tag{37}$$

1.2 Calculating β

In previous work we identified the importance of a parameter in the relativistic transformation equations of special relativity which we denoted by the Greek letter β (beta). The mathematics of indeterminacy depends on the quantity β, which occurs in the argument of the real exponential scale factor, or complex exponential phase factor that is associated with an indeterminate quantity in order to reconcile theoretical predictions with physical observations. β may be real or complex. β is characteristic of a particular spacetime manifold and it is suggested here that β defines a spacetime gauge of the type originally proposed by Weyl in 1918 that makes possible the constancy of the velocity of light We now calculate the value of β for our spacetime manifold. We do this by finding another form of γ for the transformation of energy. If the universe could be characterized by a frequency, v_0, its energy density in the interval $\Delta v = v_{0,max} - v_{0,min}$ would be given by

$$u = \frac{h\left(\nu_{0,min} - \nu_{0,max}\right)}{Volume}. \tag{38}$$

From the equation which gives the temperature of a Schwarzschild black hole, one can derive an equation for energy [2]

$$E_0 = h\nu_0 = \frac{hc^5}{16\pi^2 GkT_0}. \tag{39}$$

Applying the more general relativistic transformation (MGT) to both sides yields

$$\frac{h\nu_0\sqrt{1+\frac{uV}{w^2}}}{\left(1+\frac{u}{w}\right)}e^{-\frac{V}{u}} = \frac{hc^5\left(1+\frac{u}{w}\right)}{16\pi^2 GkT_0\sqrt{1+\frac{uV}{w^2}}}e^{\frac{V}{u}}. \tag{40}$$

This can be rearranged to give

$$\frac{hc^5}{16\pi^2 GkT_0} = h\nu_0\frac{\left(1+\frac{uV}{w^2}\right)}{\left(1+\frac{u}{w}\right)^2}e^{-\frac{2V}{u}}, \tag{41}$$

from these it follows

$$u = \frac{h\left(\nu_{0,max} - \nu_{0,min}\right)\left(1+\frac{uV}{w^2}\right)e^{-\frac{2V}{u}}}{Volume\left(1+\frac{u}{w}\right)^2}, \tag{42}$$

where $1/T_0$ is now given by

$$\frac{1}{T_0} = \frac{16\pi^2 Gkw^2}{hc^5}\frac{\left(1+\frac{uV}{w^2}\right)^{\frac{3}{2}}}{\left(1+\frac{u}{w}\right)^3}m_0 e^{-\frac{3V}{u}}, \tag{43}$$

with hv_0 given by

$$h\nu_0 = \gamma^2\left(\gamma\left(m_0 w^2\right)\right) = \gamma^3\left(m_0 w^2\right). \tag{44}$$

Since the de Broglie frequency is relativistically invariant, i.e., $v_0 = v$, it follows that the kinetic energy is invariant, i.e., $hv_0 = hv$. This means that (38) and (42) represent the same physical quantity, so that one can associate with energy a value $\gamma = 1$, so that we have

$$\gamma_{Energy} = \frac{\left(1+\frac{uV}{w^2}\right)}{\left(1+\frac{u}{w}\right)^2}e^{-\frac{2V}{u'}} =$$

$$= \frac{\left(1+\frac{u\beta}{w}\right)}{\left(1+\frac{u}{w}\right)^2}e^{-\frac{2\beta w}{u}} = 1. \tag{45}$$

For our spacetime, $u = uprime = w = c$, so that

$$\gamma_{STE} = \frac{1}{4}\left(1+\frac{V}{c}\right)e^{-\frac{2V}{c}} = 1, \tag{46}$$

or in terms of β

$$\gamma_{STE} = \frac{1}{4}\left(1+\beta\right)e^{-2\beta} = 1. \tag{47}$$

Solving this equation for β, yields

$$\beta_{ST} = -0.868683936 - 0.691575274I. \tag{48}$$

What does this β mean? Expressing β in polar notationwill make its meaning more evident

$$\beta_{ST} = 1.11035496e^{-0.785978098\pi I}. \tag{49}$$

The foundation of the calculations in this paper is the Theory of Special Relativity. At the heart of this theory is the concept of an inertial reference frame. How does one determine whether a frame of reference is inertial? Most systems of reference that we are able to use are only close approximations. However, there is general agreement that the closest we can come to a perfect inertial frame of reference is one based on the average background of all the matter in the universe [3]. The following quantity

$$\beta_{ST}c = \left[3.32876043\cdot 10^8\frac{m}{sec}\right]e^{-0.785978098\pi I}, \tag{50}$$

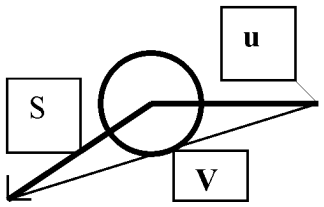

Figure 2: Diagram illustrating the application of a form of gauge invariance of the type proposed by Weyl [4] in 1918 to the invariance of spacetime velocities

represents the expansion velocity of the fabric of spacetime itself. We can use this information to compute the relative velocity of the average background of all the matter in the universe. This quantity is the difference between the velocity of spacetime itself and the outward velocities of all the objects that make up the average background of all the matter in the universe. Knowing that the object velocity for all matter is the speed of light, c, the principle of the constancy of the velocity of light would suggest that the relative velocity of the average background of all the matter in the universe would be c as well. However, because the expansion of spacetime exceeds the speed of light, we will check this assertion.

Consider the following diagram

In Figure 2, S represents the velocity of spacetime, V represents the relative velocity of the average background of all the matter in the universe, and u represents the average object velocity of the matter that makes up the average background. The following relationship holds

$$\vec{V} = \vec{s} - \vec{u}, \tag{51}$$

substituting in the appropriate values yields

$$\vec{V} = c\beta_{ST} - c = c\left(\beta_{ST} - 1\right). \tag{52}$$

Where does gauge invariance come into play? In (52), though it may not be readily apparent, there are really three unit vectors:

$$\begin{pmatrix} 1 \\ \beta_{ST} \\ \beta_{ST} - 1 \end{pmatrix} = \\ = \begin{pmatrix} e^{2\pi I} \\ 1.11035496 e^{-0.785978098\pi I} \\ 1.11035496 e^{-0.785978098\pi I} + e^{\pi I} \end{pmatrix}. \tag{53}$$

Thus, β_{ST} helps to define a Weyl gauge, such that all three velocities, measured locally may correspond identically to the speed of light, c. Not surprisingly, the gauge parameter β appears when one tries to write down an expression for the volume of the universe.

$$Volume = \frac{h\nu_0\left(1+\beta\right)}{4\left(energydensity, u\right)} e^{-2\beta}. \tag{54}$$

1.3 If rest mass is not zero, what is it? Calculating the value of the rest mass

Mass contains the phase and scale information of its associated de Broglie wave. This phase and scale information is intimately linked to spacetime. As a mass moves, its associated metric varies and its phase and scale information changes, so the value of mass changes. This corresponds to a change in the frequency of the associated de Broglie wave, or in the case of a photon, the associated electromagnetic wave. To preserve the identity of a given object one must measure with respect to a local gauge as described in the previous section. Thus, an electron remains an electron only when measured with respect to a local gauge such that its de Broglie frequency is the same for all reference frames in spacetime. This corresponds to $\gamma_{STE} = 1$ and $\beta = \beta_{ST}$. When $V = c$, in our spacetime

$$m = \frac{\sqrt{2}}{2} m_0 e^{-1}. \tag{55}$$

In terms of frequency

$$\frac{h\nu_0}{c^2} = \gamma m_0 = \frac{\sqrt{2}}{2} m_0 e^{-1} = \sqrt{2} m_a e^{-1}, \tag{56}$$

therefore

$$m_a = \frac{\sqrt{2} e h\nu_0}{2c^2}, \tag{57}$$

$$m = \frac{h\nu_0}{c^2}. \tag{58}$$

From (57, 58) one can write

$$\frac{1}{\nu_0}\left(\frac{c^2}{h} - \frac{\sqrt{2}c^2}{eh}\right) = \frac{1}{m} - \frac{1}{m_a}. \tag{59}$$

This may be rewritten

$$\frac{1}{\nu_0}\left(\frac{c^2}{h} - \frac{\sqrt{2}c^2}{eh}\right) = \frac{m_a - m}{m m_a}, \tag{60}$$

which is equivalent to

$$\frac{1}{\nu_0}\left(\frac{c^2 e^0}{h} - \frac{\sqrt{2}c^2 e^{-1}}{h}\right) = \frac{m_a - m}{m m_a}, \tag{61}$$

so that

$$\frac{c^2}{h\nu_0}\left(2\gamma_{\beta=0} - 2\sqrt{2}e^{-1}\gamma_{\beta=0}\right) = -\frac{\Delta m}{m}\left(\frac{1}{m_a}\right), \tag{62}$$

where we have used the fact that

$$\gamma = \frac{\sqrt{1+\frac{V}{c}}}{2} e^{-\frac{V}{c}} = \frac{\sqrt{1+\beta}}{2} e^{-\beta}. \tag{63}$$

Equation (62) may be rewritten

$$\frac{2c^2\gamma_{\beta=0}}{h\nu_0}\left(1-\sqrt{2}e^{-1}\right) = -\frac{\Delta m}{m}\left(\frac{1}{m_0}\right) \tag{64}$$

But this is just

$$\frac{4c^2\gamma_{\beta=0}}{h\nu_0}\left(\gamma_{\beta=0}-\gamma_{\beta=1}\right) = -\frac{\Delta m}{m}\left(\frac{1}{m_a}\right). \tag{65}$$

This may be rewritten as

$$\frac{4c^2\gamma}{h\nu_0}\left(\Delta\gamma\right) = \frac{\Delta m}{m}\left(\frac{1}{m_a}\right). \tag{66}$$

This may be converted to an integral

$$\frac{4m_a c^2}{h\nu_0}\int \gamma d\gamma = \int \frac{1}{m} dm \tag{67}$$

and integrated to give

$$\frac{4m_a c^2\gamma^2}{h\nu_0} = lnm + Constant. \tag{68}$$

We can raise each side to the base e to obtain

$$e^{\frac{4m_a c^2\gamma^2}{h\nu_0}} = e^{Constant} m \tag{69}$$

.

When $m_a = 0$, $m = m_a$, $e^{Constant} m_a = 1$ so that

$$m = m_a e^{\frac{4m_a c^2\gamma^2}{h\nu_0}}. \tag{70}$$

It should be true, when one considers the universe, that

$$\frac{mc^2}{Volume} = energy \quad density. \tag{71}$$

Therefore,

$$m_a c^2 e^{\frac{4m_a c^2\gamma^2}{h\nu_0}} = energy \quad density \cdot Volume. \tag{72}$$

So we see that for every de Broglie frequency, there is a corresponding rest mass. To find the value of m_a we need to solve the following equation

$$lnm_a + \frac{4m_a c^2\gamma^2}{h\nu_0} = ln\left(energy \quad density\right) +$$
$$+ ln\left(Volume\right) - ln\left(c^2\right). \tag{73}$$

Substituting (63) for γ and (51) for Volume yields

$$lnm_a + \frac{m_a c^2\left(1+\beta\right)e^{-2\beta}}{h\nu_0} =$$
$$= ln\left(energy \quad density\right) +$$
$$+ ln\left(\frac{h\nu_0\left(1+\beta\right)e^{-2\beta}}{4\left(energy \quad density\right)}\right) - ln\left(c^2\right), \tag{74}$$

or after combining terms on the right

$$lnm_a + \frac{m_a c^2\left(1+\beta\right)e^{-2\beta}}{h\nu_0} =$$
$$= ln\left(\frac{h\nu_0\left(1+\beta\right)e^{-2\beta}}{4c^2}\right). \tag{75}$$

Substituting the value of β for our spacetime given by (45) and substituting in the values for the appropriate constants, one obtains the following solution for m_a, which corresponds to the measured value of rest mass for an arbitrary object.

$$m_a = 2.21574666 \cdot 10^{-51}\nu_0 kg. \tag{76}$$

Equation (76) is given above operationally in the form $m_a = |z_0|\, v_0$, where z_0 is a complex constant.

1.4. Rest mass: the electron case

One can now compute the deBroglie frequency of an electron. This is found by setting m_a in (76) equal to $9.10939 \cdot 10^{-31}$ kg, the accepted measured value for the rest mass of an electron, and solving for v_0. This yields

$$\nu_{0,electron} = 4.11121 \cdot 10^{20} sec^{-1}. \tag{77}$$

A plot of rest mass vs. de Broglie frequency is shown in Figure 3.

In Figure 3, the measured rest mass of an electron is shown by the horizontal line, and is given by its accepted value as

$$m_e = 9.10939 \cdot 10^{-31} kg. \tag{78}$$

The vertical line indicates the relativistically correct de Broglie frequency of an electron, as given by (77).

For completeness, we give here the relativistic expression for the rest mass of an arbitrary object

$$m_a = \frac{h\nu_0}{c^2}\frac{e^{2\beta}L\left(\frac{1}{4}e^{-4\beta}\left(1+\beta\right)^2\right)}{\left(1+\beta\right)}, \tag{79}$$

in which $L\left(z\right)$ is a function called the $ProductLog\left[z\right]$ in Mathematica, or the $LambertW\left(x\right)$ function in Maple, where for $w = ProductLog\left[z\right]$, the following equation is satisfied

$$we^w = z \tag{80}$$

and where the principle branch of $ProductLog\left[z\right]$ is used in the evaluation of m_a.

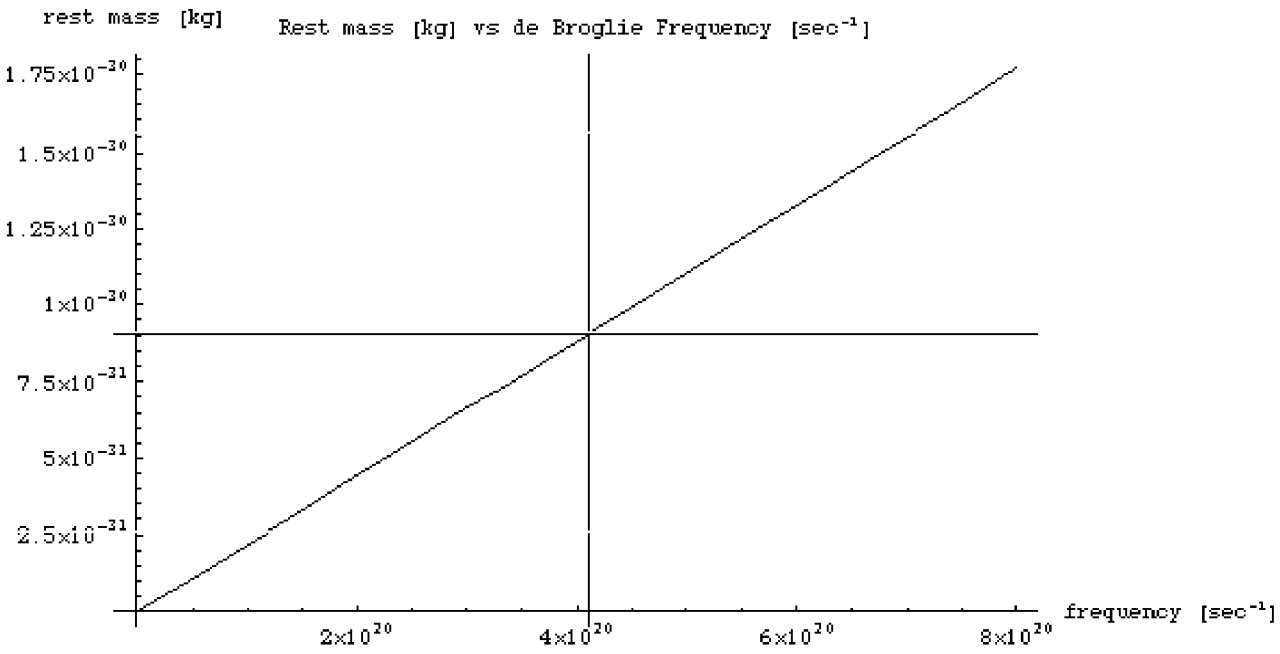

Figure 3: Plot of rest mass vs de Broglie frequency, with the electron's de Broglie frequency and rest mass shown.

1.5. Inertial mass: the electron case

Examination of the expression for m_a reveals that it contains an expression which we conventionally associate with (relativistically correct) inertial mass

$$m = \frac{h\nu_0}{c^2}. \tag{81}$$

We can now express this relativistically correct mass, m, in terms of the experimentally measured rest mass, m_a

$$m = \frac{m_a\,(1+\beta)\,e^{-2\beta}}{ProductLog\left(\frac{1}{4}e^{-4\beta}\,(1+\beta)^2\right)}, \tag{82}$$

where we have already obtained the value of $m_a\,(v_0)$ in (76). Equation (82) expresses the inertial mass in terms of the de Broglie frequency, as shown explicitly below

$$m = 2.21574666 \cdot 10^{-51} \cdot \frac{\nu_0\,(1+\beta)\,e^{-2\beta}}{ProductLog\left(\frac{1}{4}e^{-4\beta}\,(1+\beta)^2\right)}. \tag{83}$$

Using the value of β which satisfies

$$\gamma = \left[\frac{\sqrt{1+\frac{uV}{w^2}}}{\left(1+\frac{u}{w}\right)}e^{-\frac{V}{u'}}, (u = u' = w = c)\right] \Rightarrow$$

$$\Rightarrow \frac{\sqrt{1+\beta}}{2}e^{-\beta} = 1, \tag{84}$$

which we found was given by (48), now allows one to determine the electron's inertial mass from its de Broglie frequency. As we have already shown, this frequency may be found by setting the experimentally measured value of electron's rest mass, $m_a = 9.10939 \cdot 10^{-31}$ kg, equal to the right hand side of (76) and solving for v_0. In this way, the inertial mass of an electron is found to be

$$inertial \quad mass, m_{electron} = \\ = 3.03098767 \cdot 10^{-30} kg. \tag{85}$$

A plot of inertia mass as a function of de Broglie frequency is shown below in Figure 4.

In Figure 4, the inertial mass of the electron is indicated by the horizontal line, and the de Broglie frequency of the electron is shown by the vertical line. Recall that de Broglie frequency is invariant, so the frequency is the same for both the inertial mass and the rest mass. A plot of rest mass vs de Broglie frequency is also shown on the graph.

Finally, we point out that by using the mass transformation equation of the more general transformation (MGT) it is possible to associate with the inertial mass of the electron (or any arbitrary inertial mass) a corresponding object velocity. This velocity plays a role for the object which is analogous to the role played by the

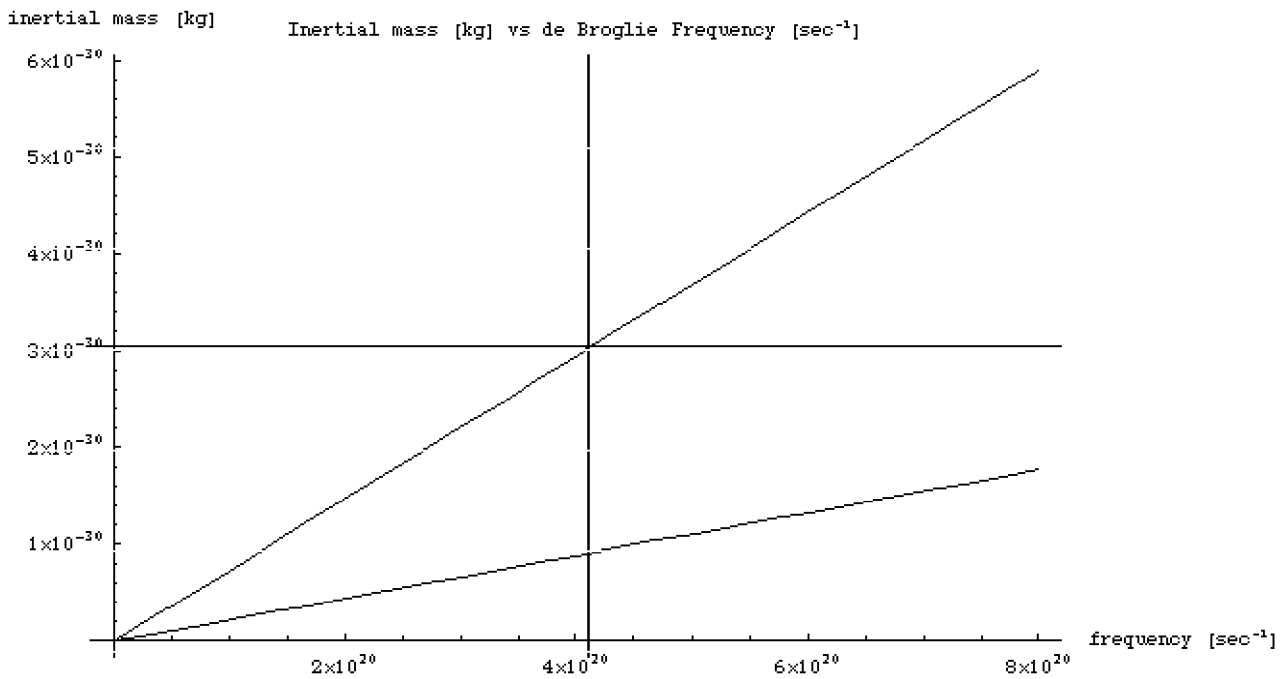

Figure 4: Plot of inertial mass as a function of de Broglie frequency, with the electron's de Broglie frequency and inertial mass shown.

speed of light for a photon in the sense that it remains constant for the object in any frame of reference. Thus, we call this velocity the Einstein inertial object velocity which we designate u_0. The corresponding de Broglie wave phase velocity will be called the de Broglie inertial phase velocity, $v_0 = c^2/u_0$, these two quantities are related in our spacetime by the relationship

$$\frac{1}{N}\sum_{n=1}^{N} u_{0n} = u, \tag{86}$$

$$\frac{1}{N}\sum_{n=1}^{N} \frac{c^2}{u_{0n}} = v, \tag{87}$$

$$w = \sqrt{uv} = c\cdot$$
$$\cdot\sqrt{(\beta_{ST} cos\,(\varphi_{ST} - \varphi_u))\,(\beta_{ST} cos\,(\varphi_{ST} - \varphi_v))}. \tag{88}$$

In which u is the average object velocity of matter that makes up the average background (shown in figure 2) and v is the average phase velocity of matter that makes up the average background, not to be confused with V, the *relative* velocity of the average background in the universe. The quantity u_0 is given by solving (45) for u with 1 on the right hand side replaced by m/m_a, and with $w = c$, and $\beta = \beta_{ST}$. The quantity w is the velocity of the matter wave wavefronts which define a particular spacetime manifold. In this sense, each type of entity makes a contribution to defining the spacetime manifold in which it is contained. In performing operations, the vector quaantities u, v, and w should be thought of as complex numbers, rather than real vectors. Equations (15-6) - (88) embody the particle essence of wave-particle duality, and as we saw earlier in our work

$$w = \sqrt{uv} = \sqrt{c\cdot c} = c, \tag{89}$$

which expresses the wave essence of wave-particle reality. Thus both aspects emerge from a model based on using a matter wave for the description of nature, so that essentially, in such a model the distinction between particle and wave are erased.

For the interested reader, we note that for an electron u_0 is given by

$$u_0 = 1.50228ce^{0.961484\pi I}\frac{m}{sec} \tag{90}$$

and

$$v_0 = 0.665655ce^{-0.961484\pi I}\frac{m}{sec}. \tag{91}$$

1.6 Duality

The relationship for inertial mass which is analogous to the one for rest mass is given by

$$m = 7.372503321\cdot 10^{-51}\nu_0 kg. \tag{92}$$

Table 1: Text of the caption

Quantity	Definition	Value
$\lvert z_0 \rvert^*$	rest mass coefficient	$2.21574666 \cdot 10^{-51} kg \cdot sec$
$\lvert z \rvert^*$	inertial mass coefficient	$7.37250332 \cdot 10^{-51} kg \cdot sec$
v_0	de Broglie frequency	$4.11121 \cdot 10^{20} sec^{-1}$
m	inertial mass	$3.03099 \cdot 10^{-30} kg$
$\lvert z \rvert c\ ^* (= h/c)$	duality parameter	$2.21022089 \cdot 10^{-42} kg \cdot m$
$(m - m_a)\, cv_0$	force of the matter wave field	$2.61298 \cdot 10^{-1} N$
$(m - m_a)\, c^2$	energy in the matter wave field	$1.90540 \cdot 10^{-13} J$
λ	de Broglie wavelength	$7.29208 \cdot 10^{-13} m$
r_0	classical electron radius	$6.05406 \cdot 10^{-16} m$

This is of the form $m = |z|\, v_0$, where z is the complex constant. One may express the de Broglie wavelength in terms of this quantity in our spacetime as

$$\lambda = \frac{h}{mu} = \frac{h}{|z|\nu_0 c}. \tag{93}$$

One may also express the de Broglie wavelength as

$$\lambda = \frac{v}{\nu} = \frac{c}{\nu_0}. \tag{94}$$

Combining (93) and (94) and rearranging yields the following result

$$h\left(\frac{1}{c}\right) = |z|c = 2.21022089 \cdot 10^{-42} kgm, \tag{95}$$

which expresses the duality of the speed of light in our spacetime.

1.7 The Inertial Force

In this final section, we examine the role of force in generating inertial mass. One may write

$$|z|c\nu_0^2 = mc\nu_0 \equiv inertial \quad force.$$

Likewise, one may write an expression for the force which generates inertial rest mass

$$|z_0|c\nu_0^2 = m_a c\nu_0 \equiv inertial \quad rest \quad force. \tag{96}$$

The difference between the two is the force associated with the object's matter wave field

$$(|z| - |z_0|)\, c\nu_0^2 = (m - m_a)\, c\nu_0 \equiv$$
$$\equiv force \quad of \quad the \quad matter \quad wavefield. \tag{97}$$

The energy contained in the matter wave field is given by

$$E = (m - m_a)\, c^2, \tag{98}$$

so that one can define a wavelength of the matter wave field

$$\lambda = \frac{E}{F} = \frac{(m - m_a)\, c^2}{(|z| - |z_0|)\, c\nu_0^2} = \frac{(m - m_a)\, c^2}{(m - m_a)\, c\nu_0} = \frac{c}{\nu_0}. \tag{99}$$

This is in agreement with the form of (94) for our spacetime.

1.8 The electron: a summary

Results for the electron are summarized in Table 1. [(*) are the same for an arbitrary mass]

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[1] The use of the notation v_1 to describe the internal frequency of a particle moving with velocity V (as observed by an external observer) which is proportional to the inverse of the period of vibration of the particle is consistent with the description of de Broglie's work presented in E. MacKinnon, "De Broglie's thesis: A critical retrospective", *Am.J. Phys.*, **44**, 1049 (1976). The subsequent concrete model presented here is adapted from this work. The reader interested in a lucid presentation of the original model should see the very readable account by L.de Broglie, "Radiation - waves and quanta: Note of Louis de Broglie, presented by Jean Perrin", translated from *Comptes rendus*, **177**, (1923). pp. 507-520.

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THE GRAVITATIONAL MASS OF THE ELECTROMAGNETIC FIELD

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It is considered the interpretation of the theory of relativity in which all relativistic phenomena pertain only to electromagnetism while gravitation remains non-relativistic. It is derived the relation between the gravitational mass and the electromagnetic energy in the Newtonian mechanics. It is shown that description of the bending of light by a gravitating body in the Newtonian mechanics gives the same result as that in the general relativity.

In a number of papers [1, 2, 3, 4, 5, 6] the interpretation of the theory of relativity was developed. The theory reinterpreted is based on the dual nature of the electromagnetic field as follows from the quantum mechanics. Then one can consider the quasi-classical electrodynamics in which coordinate and dynamical parameters of the electromagnetic field are independent due to the Heisenberg uncertainty principle.

As known the Maxwell-Lorentz equations for the scalar potential φ and the vector potential $\vec{A}$ describe electromagnetic field as a wave

$$\triangle\varphi - \frac{1}{c^2}\frac{\partial^2\varphi}{\partial t^2} = 0 \tag{1}$$

$$\triangle\vec{A} - \frac{1}{c^2}\frac{\partial^2\vec{A}}{\partial t^2} = 0 \tag{2}$$

where $\triangle$ is the Laplacian, c is the velocity of light. Consider electromagnetic field within the framework of Newtonian mechanics. The Newtonian principle of relativity based on the Lorentz transformation calls for two inconsistent claims to the velocity of light. On the one hand, the velocity of light should follow the Galilean composition law hence should be a function of the velocity of the frame. On the other hand, the velocity of light is a fundamental constant hence should be fixed in all the frames. We shall incorporate this contradiction into the theory by introducing an additional law for the velocity of light. This is the well known Einstein postulate of invariance of the velocity of light

$$\frac{l}{t} = c. \tag{3}$$

Thus we have two inconsistent velocities of light, the first, invariant, given by the Einstein postulate, the second, non-invariant, given by the Maxwell-Lorentz equations. Suppose that the invariant velocity of light given by the Einstein postulate incomes the Maxwell-Lorentz equations. The velocity of light outgoing the Maxwell-Lorentz equations will be non-invariant.

It is natural to think that the Einstein postulate specifies the space and time while the Maxwell-Lorentz equations yield the electromagnetic potentials in this space and time. The problem may be understood within the quantum mechanics [1]. Since electromagnetic field is a quantum object, its space coordinate and momentum (time coordinate and energy) are bound with the Heisenberg uncertainty principle. When determining the coordinate parameters of the electromagnetic field we cannot determine the dynamical parameters of the electromagnetic field. Then we should consider electromagnetic field as a massless particle the motion of which yields the coordinate parameters of the electromagnetic field. Equation (3) describes the motion of a massless particle. When determining the dynamical parameters of the electromagnetic field we cannot determine the coordinate parameters of the electromagnetic field. Then we should consider electromagnetic field as a wave, with the Maxwell-Lorentz equations yielding the dynamical parameters of the electromagnetic field.

The velocity of light given by eq. (3) relates the scales of length and time. Equation (3) is invariant under the Galilei transformation. Thus the postulate of invariance of the velocity of light specifies the Euclidean space and the absolute time. Apply the Galilei transformation to the Maxwell-Lorentz equations. We obtain the variation of the electromagnetic potentials in the moving frame

$$\varphi, \vec{A} \propto \frac{(1 - v^2/c^2)^{1/2}}{1 \pm v/c}. \tag{4}$$

Thus the electromagnetic potentials follow the Lorentz transformation.

It is reasonable to enunciate the principle of relativity in the electrodynamics as invariance of the velocity

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of light given by the Einstein postulate [5]. Since the Einstein postulate ensures the invariant velocity of light as well as the invariant scales of length and time there is no need in invariance of the Maxwell-Lorentz equations. Then we consider electrodynamics in the Euclidean space and the absolute time. Since we refused from invariance of the Maxwell-Lorentz equations there is no need in double standards for the scale of electromagnetic energy. Then both observers in the rest and in the moving frames view the electromagnetic energy in the moving frame decreasing as $\mathcal{E} \propto (1 - v^2/c^2)^{1/2}$.

Consider the dynamics of the electron with the charge e and the mass m in the electromagnetic field with the strength E [2]. In the frame moving with the speed v, the acceleration experienced by the electron is given by

$$w' = \frac{eE}{m}(1 - v^2/c^2)^{1/2}. \tag{5}$$

One can treat eq. (5) as a decrease of the ratio of electromagnetic energy and inertial mass in the moving frame. The usual interpretation of eq. (5) is that the mass of the electron in the moving frame increases, $m \propto (1 - v^2/c^2)^{-1/2}$. From this it follows the relativistic dynamics [7]. But the increase of the mass happens only with respect to the electromagnetic energy. It is reasonable to think that the mass remains fixed in the gravitational interaction. Then all relativistic phenomena pertain only to electromagnetism while gravitation remains non-relativistic.

So the relativistic dynamics holds true only for the electromagnetic interaction (we can extend the validity of the relativistic dynamics to the weak and strong interaction since they are governed by the electromagnetic charge). We shall treat gravitation as non-relativistic and describe it within the Newtonian mechanics. It is worth to stress once again that the relativistic increase of mass matters only with respect to the electromagnetic energy. The well known relation $\mathcal{E} = mc^2$ of the Einstein special relativity [7] makes sense only for the mass with respect to the electromagnetic energy.

Consider the relation between the gravitational mass and the electromagnetic energy within the Newtonian mechanics. Put the particle of the mass m moving with the speed of light into correspondence with the electromagnetic field of the energy $\mathcal{E}$. Then the kinetic energy of the particle is equivalent to the electromagnetic energy

$$\mathcal{E} = \frac{1}{2}mc^2. \tag{6}$$

This means that the electromagnetic field possesses the gravitational mass and can take part in the gravitational interaction. Remind that we consider propagation of the electromagnetic field as a massless particle independently from its dynamical behaviour. The electromagnetic field as a particle of the mass m suffers the attraction of a gravitating body. Let the electromagnetic field move transversely to a gravitating body. At a length Δl, the electromagnetic field acquires the radial momentum due to the gravitational potential Φ

$$\Delta p_r = \frac{m\Phi\Delta l}{cr} = \frac{2\mathcal{E}\Phi\Delta l}{c^3 r}. \tag{7}$$

The deflection of the electromagnetic field at a length Δl is given by

$$\Delta\theta = \frac{\Delta p_r}{p} = \frac{2\Phi\Delta l}{c^2 r} \tag{8}$$

wherein we use the expression for the momentum of the electromagnetic field

$$p = \frac{\mathcal{E}}{c}. \tag{9}$$

We obtain the same result as in the general relativity. Remind [7] that the experimental data support this result.

Thus the true description of the bending of light by a gravitating body is possible in the Newtonian mechanics. This means that the effect cannot serve as an evidence for the general relativity rather than the Newtonian mechanics. Another effect of the general relativity, the gravitational redshift of the electromagnetic field, can be described within the special relativity with the use of the Einstein principle of equivalence [7]. The third effect considered as an evidence for the general relativity, the anomalous shift of the perihelion of Mercury, can be explained with the hypothetical fixed potential of the Sun [8]. It is shown that the hypothetical fixed potential of the Sun can also explain the anomalous acceleration of Pioneer 10, 11 and the anomalous acceleration of the Moon. Thus the three effects considered as evidences for the general relativity can be explained within the Newtonian mechanics and special relativity.

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AN IMMEDIATE PROOF OF THE NON-EXISTENCE OF GW'S

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In general relativity (GR) no observer is physically privileged. As a strict consequence, it can be shown that the physical generation of gravitational waves (GW's) is quite impossible.

1. As it is well known, the notion of GW came forth as a by-product of the **linear** approximation of GR [1]. Now, this approximation – which *resembles* Maxwell e.m. theory – is fully **inadequate** to a proper study of the hypothetic GW's (see [2], [3]). On the other hand, in the **exact** (non-approximate) formulation of GR **no** "mechanism" exists in reality for the *physical generation* of the GW's, as it can be proved [3]. The undulatory solutions of Einstein field equations have a mere *formal* character.

I give here **another** proof of the real non-existence of *physical* GW's, which is so straightforward that even the physicist in the street will understand it.

2. There is a **radical** difference between Maxwell e.m. theory and Einstein general relativity: Maxwell theory is Lorentz invariant, the set of the inertial observers is *physically* privileged – Einstein theory has an invariant character with respect to *all* transformations of general co-ordinates, and *no* observer is *physically* privileged [4]. *All* observers are on an equal physical footing just like the *inertial* observers in Maxwell theory. (Strictly speaking, in GR the concept "observer" requires a particular specification [5]).

3. An electric charge C which is *at rest* for a given *inertial* observer I_0 cannot emit e.m. waves. Any inertial observer I for whom C is in motion does not possess physical privileges with respect to I_0. Accordingly, both observer I_0 and observer I do not register any e.m. wave sent forth by C.

In GR the expression *at rest* must be defined precisely every time, *specifying the interested spacetime manifold*, because the co-ordinates are mere "labels" of point events [5]. Let us consider for instance the Einsteinian gravitational field generated by a homogeneous sphere of an incompressible fluid as it was investigated by Schwarzschild [6]. In Schwarzschild's system of co-ordinates S_0 the sphere is at rest, and no GW is emitted. Now, any observer S – very far, in particular, from observer S_0, for whom the sphere of fluid is in motion does not possess any physical privilege with respect to S_0. Accordingly, both observer S_0 and observer S do not register any GW sent forth by the sphere of fluid. It is evident that this argument can be extended to any celestial body B, which can be considered at rest for a given observer S_0 and in motion for any observer S, who is very far, in particular, from S_0. *Q.e.d.*

APPENDIX

α) I have repeatedly emphasized in my papers that the notion of GW was originally (1916-1918) a by-product of the **linearized** version of the exact (nonlinear) formulation of GR. This circumstance has unduly influenced almost all the subsequent researches (both theoretical and experimental) concerning the GW's. The great majority of the physicists have considered their existence as an obvious fact, not deserving the proof given by a real existence theorem. Even today the overwhelming majority of the experimentalists know only Einstein's old papers [1]. The superficial (and *false*) analogy with Maxwell e.m. theory has generated ruinous consequences. Thus, since forty years the GW hunters persist in their vain efforts aimed at the experimental detection of GW's. In the last years the inconclusive conclusions of their papers have assumed a pathetic character of the following kind: No gravitational wave was observed; however, the search provided us with an encouraging upper limit on the gravity wave strain at our apparatuses.

β) I reproduce here the abstract and the third paragraph of the Introduction of a recent paper by S.D. Mohanty, Sz. Márka, *et alii*, entitled "Search algorithm for a gravitational wave signal in association with Gamma Ray Burst GRB030329 using the LIGO detectors" [7]. The abstract is as follows: "One of the brightest Gamma Ray Burst ever recorded, GRB030329, occurred [on 29 March 2003] during the second science run of the LIGO detectors. At that time, both interferometers at

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the Hanford, WA LIGO site were in lock and acquiring data. The data collected from the two Hanford detectors was [*sic*!] analyzed for the presence of a gravitational wave signal associated with this GRB. This paper presents a detailed description of the search algorithm implemented in the current analysis." And the third paragraph of the Introduction tells us that: "The search algorithm is the component which acts on preprocessed data and produces a list of candidate events or the value of a statistics which is then used in drawing a statistical inference. A first version of a full analysis pipeline was reported in Mohanty S.D. *et al.* 2004 *Class. Quantum Grav.* **21** S765-S774 and the pipeline used for the present analysis will be described in LIGO Science Collaboration: Abbott B. *et al.* 2004 *To be submitted.*"

Now, a report on INTERNET (13 January 2004) by the second author of the above paper (Sz. Márka) has informed us that "We did not observe a gravity burst, which can be associated with GRB030329." Any comment is superfluous.

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Bondi *et alii* – see H. Bondi, F.A.E. Pirani and I.Robinson, *Proc. Roy. Soc.*, **A 251** (1959) 219 – claimed to have proved the existence of a class of privileged reference frames insofar as the GW's are concerned, but their "proof" is no proof.

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VOLUMETRIC POLARIZATION MODEL OF HYDROGEN ATOM

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The volumetric model of a hydrogen atom in which as a first approximation the proton is represented as the cylinder of the terminating sizes is considered. The proton will consist of the positive point charge (positron), the positive charge (plurality of positrons) and the negative charge (plurality of electrons) which enclose a positron and are equal on an absolute value. Both redistribution of a charge of a proton (polarization) and change of the geometrical sizes of a proton happens as a result of interaction of charges of a proton to an outer-shell electron. Parameters of model are spotted by a method of optimization (on three spectral lines of a series of Lajman). It set, that the experimental and settlement spectrums differ on quantity from 0.02 proton is given. It is shown, why the mobile electron cannot penetrate inside of a proton.

The present work is prolongation of works on making physical polarization model of hydrogen atom [1, 2].

As a first approximation to volumetric model of a hydrogen atom we shall present a proton as the cylinder of the terminating sizes. A dot electron is located outside of the cylinder and the axis of the cylinder and a dot electron are located on one line. The proton include the positive point charge (positron) and the positive charge (set of positrons) and the negative charge (set of electrons) which are equal on an absolute value and are surround the positron.

Both redistribution of a charge of a proton (polarization), and change of the geometrical sizes of a proton happens as a result of interaction the charges proton with the outer-shell electron. The degree of polarization and deformation depends on cross distance of an electron and a proton. We shall consider, that the volume of a "cylindrical" proton remains to stationary values and equal to volume of the free "spherical" proton.

Let's apply the generalized cylindrical frame (fig. 1).

$$
\begin{aligned}
&X = R \cdot \rho \cdot cos\,(\varphi)\,,\\
&Y = R \cdot \rho \cdot sin\,(\varphi)\,,\\
&Z = \tfrac{L}{2} \cdot u;\\
&0 \le \rho \ge 1,\\
&0 \le \varphi \ge 2 \cdot \pi,\\
&-1 \le u \ge 1;\\
&R = f1\,(r) \cdot \tfrac{d}{2},\\
&L = f\,(r) \cdot d,
\end{aligned}
\tag{1}
$$

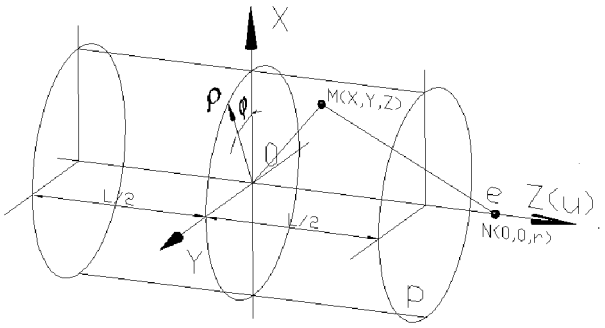

Figure 1: A cylindrical frame

where R, L, d, r are accordingly the radius and the length of a polarized proton, the diameter of the free proton and the distance between centre of a proton p and an electron e^-; $f1\,(r)$, $f\,(r)$ are the functions which are taking into account deformation of a proton at polarization.

Let's put, that the proton is polarized along lines, parallel axes of the cylinder, i.e. axis $Z\,(u)$. In this case a density of charge δ at polarization of a proton we shall present as:

$$
\begin{aligned}
\delta\,(r,u) &= \Delta\,(r) \cdot cos\left(\tfrac{2 \cdot \pi \cdot z}{L} + \alpha\,(r)\right) =\\
&= \Delta\,(r) \cdot cos\,(\pi \cdot u + \alpha\,(r))\,,
\end{aligned}
\tag{2}
$$

where $\Delta\,(r)$ is amplitude of a charge distribution.

On definition the quantity of a charge Q together with (1) is equal:

$$
Q\,(r) = \int\limits_0^1 J \cdot \rho d\rho \int\limits_0^{2 \cdot \pi} d\varphi \int\limits_{-1}^{1} \delta\,(r,u)\,du\,, \tag{3}
$$

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where

$$J = f1^2(r) \cdot f(r) \cdot \frac{d^3}{8}. \quad (4)$$

From (2) and (3) follow the relations:

$$Q(r) = 0, \quad (5)$$

$$Q(r) = Q_1(r) + Q_2(r), \quad (6)$$

where

$$Q_1(r) = \int_0^1 J \cdot \rho d\rho \int_0^{2\cdot\pi} d\varphi \int_{-1/2}^{1/2} \delta(r,u) du =$$

$$= 2 \cdot J \cdot \Delta(r) \cdot cos(\alpha(r)), \quad (7)$$

$$Q_2(r) = \int_0^1 J \cdot \rho d\rho \int_0^{2\cdot\pi} d\varphi \int_{-1}^{-1/2} \delta(r,u) du +$$

$$+ \int_0^1 J \cdot \rho d\rho \int_0^{2\cdot\pi} d\varphi \int_{1/2}^{1} \delta(r,u)\, du =$$

$$-2 \cdot J \cdot \Delta(r) \cdot cos(\alpha(r)), \quad (8)$$

Apparently from (7) and (8), the basic property of a charge $Q_1 = -Q_2$ of viewed model of a proton is fulfilled at any distance r between an electron and a proton.

From (7) follows:

$$Q_1(r) = Q_0(r) \cdot cos(\alpha(r)),$$

where

$$Q_0(r) = 2 \cdot J \cdot \Delta(r), \quad (9)$$

Having presented $Q_0(r)$ as product of number of particles $N(r)$ and quantities of a charge of a particle q, we discover $\Delta(r)$:

$$\Delta(r) = \frac{N(r) \cdot q}{2 \cdot J}. \quad (10)$$

Energy of a Coulomb interaction $W(r)$ of an electron with charges of a proton is equal:

$$W(r) = W_q(r) + W_\delta(r), \quad (11)$$

where (see also fig. 1)

$$W_q(r) = -\frac{q}{4 \cdot \pi \cdot \varepsilon_0 \cdot r}, \quad (12)$$

$$W_\delta(r) = -\frac{q}{4 \cdot \pi \cdot \varepsilon_0} \cdot \int_0^1 J \cdot \rho d\rho \int_0^{2\cdot\pi} d\varphi \int_{-1}^{1} \frac{\delta(r,u)}{MN} du =$$

$$= -\int_0^1 J \cdot \rho d\rho \int_0^{2\cdot\pi} d\varphi \cdot$$

$$\cdot \int_{-1}^{1} \frac{\delta(r,u)}{\sqrt{\left(f1(r) \cdot \frac{d}{2}\right)^2 + \left(r - f2(r) \cdot \frac{d}{2}\right)^2}} du, \quad (13)$$

here $W_q(r)$ is an electrostatic energy between an electron and a positron (between an electron and a proton in the conventional model of a hydrogen atom);

$W_\delta(r)$ is an electrostatic energy of an electron with the distributed charge of a proton;

q is quantity of a charge of a positron.

From a requirement of a constancy of volume of a proton follows, that functions $f1$ and f are locked-in by a relation:

$$f1^2 = \frac{2}{3 \cdot f}. \quad (14)$$

Using (2), (4), (10), (13), (14), and accepting a dimensionless quantity of distance x by means of replacement $r = x \cdot d$, after integration (13), we shall receive a relation for an electrostatic energy $W(x)$ (expressed in eV) as

$$W(x) = -\frac{q}{4 \cdot \pi \cdot \varepsilon_0 \cdot d} \cdot (3 \cdot N(x) \cdot \pi \cdot f(x) \cdot$$

$$\cdot \left(I(x) - \frac{2 \cdot f(x) \cdot sin(\alpha(x))}{\pi}\right) + \frac{1}{x}), \quad (15)$$

where

$$I(x) = \int_{-1}^{1} \left(\sqrt{\frac{2}{3 \cdot f(x)} + (2 \cdot x - f(x) \cdot u)} -\right.$$

$$\left. - (2 \cdot x - f(x) \cdot u) \cdot cos(\pi \cdot u + \alpha(x))\right) du.$$

Let's present unknowns function $N(x), f(x), \alpha(x)$ by relations:

$$N(x) = \frac{Nmax \cdot fN(x)}{fNmax};$$

$$f(x) = k \cdot \left(1 + \frac{p_1 \cdot (x - x0)^{p_2}}{1 + p_3 \cdot (x - x0)^{p_4}}\right); \quad (16)$$

$$\alpha(x) = p_5 \cdot (x - x0),$$

where

$$fN(x) = \frac{1 + p_6 \cdot (x - x0)^{p_7} + p_8 \cdot (x - x0)^{p_9} + p_{10} \cdot (x - x0)^{p_{11}}}{1 + p_{12} \cdot (x - x0)^{p_{13}} + p_{14} \cdot (x - x0)^{p_{15}}};$$

$$x0 = \frac{k}{2};$$

$p_i, i = (1, 2, ..., 15)$ is elements of a vector p unknowns parameters of model; $fNmax$ is the peak value of function $fN(x)$; k is coefficient, defining the geometrical sizes of the free proton; $Nmax$ is the peak number of electron-positron pairs.

The procedure of a finding of parameters of model of a hydrogen atom, calculation of its spectrum, evaluation of diameter of a unpolarized proton explicitly are circumscribed in work [3].

As a result of optimization (on three spectral lines of a series of Lajman) values of parameters of model p have made:
$p_1 = 3.302868266 \cdot 10^{-4}$; $p_2 = 1.131433454$;
$p_3 = 6.902031929 \cdot 10^{-6}$; $p_4 = 9.630091684 \cdot 10^{-1}$;
$p_5 = 0.035$; $p_6 = -1.183447769 \cdot 10^{-1}$;
$p_7 = 1.001666818$; $p_8 = 3.049549194$;
$p_9 = 7.977595044 \cdot 10^{-3}$; $p_{10} = 1.392328128$;
$p_{11} = 6.629697611 \cdot 10^{-1}$; $p_{12} = 2.6447764838$;
$p_{13} = -1.080067296$; $p_{14} = 4.356227738 \cdot 10^{-8}$;
$p_{15} = 2.425221334$.

Thus the peak number of the electron-positron pairs participating in polarization, diameter of a unpolarized proton and coefficient k are accordingly equal:

$$Nmax = 1188, \quad d = 4.71 \cdot 10^{-12} m, \quad k = 1.18.$$

The odds between mass of electron-positron pairs which are in the free state, and in mass created of them a proton makes flaw of mass of a proton Δm. Presence of flaw of mass of a proton immediately determines its stability which is characterized by a binding energy W:

$W = \Delta m \cdot c^2 = (2 \cdot Nmax \cdot m_e - m_p) \cdot c^2$, where m_e is mass of an electron; m_p is mass of a proton; c is velocity of light.

As $m_p = 1836 \cdot m_e$ and $m_e \cdot c^2 = 0.511 Mev$ the estimation of a binding energy of a proton gives value $276 Mev$.

Settlement $\lambda_{j,1}$ and experimental $\lambda 0_{j,1}$ values of spectral lines of a series of Lajman, and also their relative diversions $\delta\lambda_{j,1}$ are submitted in the table. Apparently, the experimental and settlement spectrums differ on an absolute value in limits from 0.02 % up to 0.4 %.

On fig. 2 the diagrams of energies $W(r)$ and $Wq(r)$ a Coulomb interaction of an electron according to a charge of a nucleus of viewed model of a hydrogen atom and a proton of the conventional model are submitted.

Essential circumstance is that in viewed model the electrostatic energy $W(r)$ at $r > \quad 0.5nm$ is featured by the continuous periodic curve, and at $r < 0.5nm$, accepting the positive value, will continuously increase at approach of an electron to boundaries of a proton. The last speaks that, since $r < 0.5nm$, between an electron and a proton there is only a repulsive force which hinders with the further coming together of an electron with a proton.

Table 1: The experimental and settlement quantities of a spectrum of a hydrogen atom (symbol "*" mark the lines for which a spectrum optimization was carried out.)

j	$\lambda 0_{j,1}, nm$	$\lambda_{j,1}, nm$	$\delta\lambda j, 1, \%$
2*	121.5670	121.5484	$-1.53 \cdot 10^{-2}$
3*	102.5720	102.6593	$8.51 \cdot 10^{-2}$
4*	97.2537	97.2052	$-5.00 \cdot 10^{-2}$
5	94.9743	94.9042	$-7.4 \cdot 10^{-2}$
6	93.7803	93.7589	$-2.28 \cdot 10^{-2}$
7	93.0748	93.1276	$5.67 \cdot 10^{-2}$
8	92.6226	92.7529	$1.41 \cdot 10^{-1}$
9	92.3150	92.3498	$3.77 \cdot 10^{-2}$
10	92.0963	92.2542	$1.72 \cdot 10^{-1}$
11	91.9352	92.1693	$2.55 \cdot 10^{-1}$
12	91.8129	92.0945	$3.07 \cdot 10^{-1}$
13	91.7181	92.0287	$3.39 \cdot 10^{-1}$
14	91.6429	91.9708	$3.58 \cdot 10^{-1}$
15	91.5824	91.9196	$3.68 \cdot 10^{-1}$
16	91.5329	91.8742	$3.73 \cdot 10^{-1}$

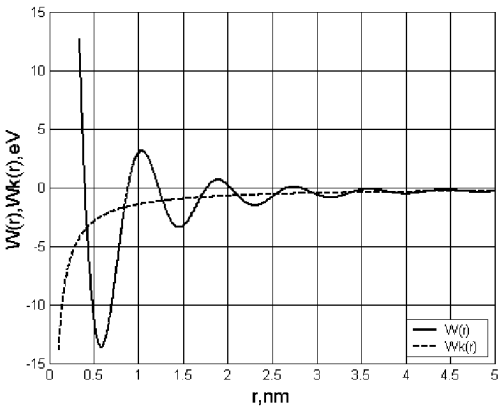

Figure 2: The diagram of an electrostatic energy of an electron with a proton.

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PHYSICAL NATURE OF GRAVITATIONAL AND INERTIAL FORCES

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The representation about physical substance of a gravitation is given.

The geometrical representation of a gravitational field as a curvature of spatial and time continuum was given by Einstein. However such representation does not give the imagination about physical essence of a gravitation. Exploring the electromagnetic field properties of the relativistic magnetic rotator (RMR), (more detailed about the RMR properties on the site http://scherbakv.narod.ru), the author has paid attention to the inner link of an electrodynamics and gravitation in the General Relativity (GR). The values of dielectric ε and magnetic μ penetrations of physical vacuum [1] change depending on the value of the scalar gravity potential occurring both in the rotating system as well as around gravitating masses. According to Maxwell's equations in gravitational fields we have [2,3]:

$$\mu = \varepsilon = \frac{1}{\sqrt{1 + 2\chi/c^2}}, \tag{1}$$

where c is the light speed, χ is the scalar gravity potential. The scalar gravity potential is the unique characteristic of the gravitational field spatial distribution around the gravitating masses. This potential gradient, according to GR, characterizes the space curvature, it is numerically equal to the free fall acceleration $\operatorname{grad}\chi = -a$. According to the electrodynamics rate of electromagnetic oscillations propagation (the light speed) c depends on the values of the medium dielectric and magnetic penetrations. According to RT the dielectric and magnetic penetrations depend on a scalar gravity potential [1,2], therefore:

$$c = \frac{1}{\sqrt{\mu\varepsilon}} = c_0\sqrt{1 + 2\chi/c_0^2}. \tag{2}$$

We shall express the scalar gravity potential through the light speed from the formula (1).

$$\chi = \frac{c^2}{2} - \frac{c_0^2}{2}. \tag{3}$$

In the force system, where $c_0 = \mu_0 = \varepsilon_0 = 1$, we shall receive:

$$\chi = \left(c^2 - 1\right)/2 = \left(\frac{1}{\mu\varepsilon} - 1\right)/2. \tag{4}$$

The formula (4) shows that dielectric ε and magnetic penetrations give the complete characteristic of the gravitational field distribution. Thus there is a physical sense of the gravitational field as the gradient of inner, latent properties of space. The vacuum physical properties — the dielectric and magnetic penetrations change around the gravitating masses from point to point, i.e. the space becomes non-uniform for electromagnetic fields.

The light speed changes depending on the scalar gravity potential (2) in GR. It is constant in all inertial reference systems in SR. There are no contradictions in this case. The direct measurements of the light speed made by the same length and time models in various systems will give the same measuring result. It is possible to measure the light speed only by indirect method being in other system on gravitational frequency shift. The scalar gravity potential decreases with the moving off the Sun and the light speed, measured from the Earth surface, increases according to the ratio (2).

The environment behaves similarly to the medium for electromagnetic fields that changes its inner physical properties according to the scalar gravity potential. The half of the velocity squared for the derivative mass determines the kinetic energy of this mass, therefore, the half of the light speed squared (or gravity potential) can determine the inner, latent kinetic energy of the vacuum volume unit according to (3). The physical essence of the gravitational field can be defined as the gradient of the vacuum latent inner energy. The calculations show that the gravitating masses, stars reduce the light speed in the environment in thousandth percent shares. We can say that the vacuum huge inner energy at the formation or approach of astronomical objects decreases in insignificant small value. The energy density decrease in the space area having massive

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bodies is obliged to the least action principle. The gravitational force affecting on the body is equal to the potential energy gradient and directed on the body energy reduction. As the gravitational forces are always directed to the gravitating masses approach, so the energy density in the environment decreases at the approach or formation of massive bodies. The weak density gradient of inner latent energy represents the gravitational field occurring in space.

This physical representation of the gravitational field is the consequence of GR and there are no doubts in its correctness. It indicates the probable physical nature of gravitational and inertial forces. If to assume that all elementary particles have wave, electromagnetic nature and are the solitons in the vacuum, so such solitons change their potential energy depending on the value of the scalar gravity potential according to the theory [4]. The gradient of the vacuum inner, potential energy is responsible for the force occurrence affecting on a soliton or group of solitons forming a body. This force is numerically equal to the gradient making of the potential energy (the gravity potential gradient equal to acceleration) on the soliton energy (the equivalent value of the body mass) that meets the first Newton's law. The soliton or soliton group, forming the body, will have the same acceleration numerically equal to the free fall acceleration in the gradient field of dielectric and magnetic penetrations. Therefore it is possible to assume that the physical nature of forces occurring in a gravitational field, connected to the varying vacuum inner properties (the latent energy gradient) and soliton nature of both elementary particles and all material bodies.

The dielectric and magnetic penetrations are constant in the space area remote from the gravitating masses. Such space is uniform, and the gradient of a scalar gravity potential is equal to zero. The elementary particles, atoms, moving with constant speed in similar space, are in weightlessness, as they do not change their energy. The vector gravity potential numerically equal to acceleration (at small, non-relativistic velocities) [2,4] appear at the travelling velocity change of the soliton v. The speeded up moving body changes its kinetic energy equal to $mv^2/2$ at small velocity values. Therefore the external forces increase the total energy of medium and body (the solitons accumulation) at the body acceleration. The force on the medium part begins to act instantaneously that interferes its energy increase. The occurring energy gradient (the gradient χ) from the gravitating mass or velocity change is perceived by the body as homogeneous, non-distinguishable forces in the frame of reference connected with the body. The soliton model of elementary particles and the gradient ε, μ, created by massive bodies, causing the heterogeneity of the vacuum inner properties, allow explaining both the inertial properties of material bodies and gravitational forces nature. The author considers that the vacuum inner physical properties are responsible solely for all observed electromagnetic phenomena. The electrodynamics is considered as the special physics part non-connected with the mechanics and medium theory without justifying. The unique properties of the environment allow the nature to create and change the whole world and all observed interactions, having only one building material - the vacuum available.

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ALL-SUFFICIENT POLARIZING MODEL OF HYDROGEN ATOM

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Volumetric model of hydrogen atom where the proton has the form of ellipsoid of the final sizes is considered. The proton consists of a positive dot charge (positron) and a positive charge (set of positrons) which it is surrounded a positron and a negative charge (set of electrons), positive and negative charge is equaled on absolute size.
As a result of interaction of charges of a proton to external electron there is both redistribution of a charge of a proton (polarization), and change of the geometrical sizes of a proton.
Parameters of model are determined by optimization technique (on three spectral lines of Lajman's series). It is determine that the experimental and design (the lines which are not participating in optimization) spectra differ in limits from 0.1% to 0.6%. Proton binding energy is calculated. It is show why a free electron does not to penetrate into proton. This testifies that the polarizing model of hydrogen atom is all-sufficient.

The present work is one of the closing stages on creation of physical polarizing model of hydrogen atom [1, 2, 3].

In the present model of hydrogen atom the proton has the form of ellipsoid of the final sizes. The dot electron which is taking place outside of ellipsoid is located on a direct line which passes through one of axes of ellipsoid. The proton consists of a positive dot charge (positron) and a positive charge (set of positrons) which it is surrounded a positron and a negative charge (set of electrons), positive and negative charge is equaled on absolute size (fig. 1).

As a result of interaction of charges of a proton to external electron there is both redistribution of a charge of a proton (polarization), and change of the geometrical sizes of a proton. The degree of polarization and deformation depends on mutual distance of electron and a proton. We shall consider that the volume of a proton remains constant and equal to volume of a free "spherical" proton.

Let's enter the generalized cylindrical system of coordinates (fig. 1).

$$X = a \cdot \rho \cdot cos\,(\varphi)\,,\; Y = a \cdot \rho \cdot cos\,(\varphi)\,,\; Z = b \cdot u;$$

$$0 \le \rho \ge 1,\; 0 \le \rho \ge 2 \cdot \pi,\; -1 \le u \ge 1; \qquad (1)$$

$$a = f1\,(r) \cdot \frac{d}{2},\; b = f\,(r) \cdot \frac{d}{2},$$

where: a and b is semi-axises size of a proton ellipsoid; d is diameter of a free proton; r is distance between electron e^- and a positron e^+ which taking place in the center of a proton p; $f1\,(r)$, $f\,(r)$ the functions

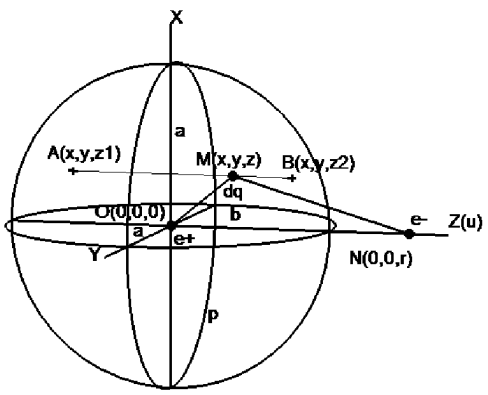

Figure 1: Model of hydrogen atom

which are taking into account deformation of a proton at polarization.

From a condition of a constancy of a proton volume follows that functions $f1\,(r)$ and $f\,(r)$ are connected by a ratio:

$$f1\,(r) = \frac{1}{\sqrt{f\,(r)}}. \qquad (2)$$

Let's put, that the proton is polarized along the lines parallel to axis $Z\,(u)$. On a line of polarization in length AB the density of a proton charge δ we shall present as:

$$\delta\,(r) = \Delta\,(r) \cdot cos\left(\frac{2 \cdot \pi \cdot Z}{AB} + \alpha\,(r)\right),$$

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where $\Delta(r)$ is amplitude of distribution of a charge, $\alpha(r)$ is an initial phase. And as $AB = 2 \cdot b \cdot \sqrt{1-\rho^2}$,

$$\delta(r,u) = \Delta(r) \cdot cos\left(\frac{\pi \cdot u}{\sqrt{1-\rho^2}} + \alpha(r)\right). \quad (3)$$

By definition the value of a charge is equal: $Q = \iiint\limits_V \delta(r,Z)\,dV$, that in common with (1) and (2) gives:

$$Q(r) = \frac{d^3}{8} \cdot \int\limits_0^1 \rho d\rho \int\limits_0^{2\cdot\pi} d\varphi \int\limits_{-\sqrt{1-\rho^2}}^{\sqrt{1-\rho^2}} \delta(r,u)\,du. \quad (4)$$

From (3) and (4) follows, that the value of a charge $Q(r) = 0$, positive $Q_+(r)$ and negative $Q_-(r)$ charges are equal:

$$Q(r)_+ = \frac{d^3}{8} \cdot \int\limits_0^1 \rho d\rho \int\limits_0^{2\cdot\pi} d\varphi \int\limits_{\frac{-\sqrt{1-\rho^2}}{2}}^{\frac{\sqrt{1-\rho^2}}{2}} \delta(r,u)\,du =$$

$$= \frac{\Delta(r) \cdot d^3 \cdot cos(\alpha(r))}{6}, \quad (5)$$

$$Q(r)_- = \frac{d^3}{8} \cdot \int\limits_0^1 \rho d\rho \int\limits_0^{2\cdot\pi} d\varphi \int\limits_{-1}^{\frac{-\sqrt{1-\rho^2}}{2}} \delta(r,u)\,du +$$

$$Q(r)_- = \frac{d^3}{8} \cdot \int\limits_0^1 \rho d\rho \int\limits_0^{2\cdot\pi} d\varphi \int\limits_{-1}^{\frac{-\sqrt{1-\rho^2}}{2}} \delta(r,u)\,du +$$

$$+\frac{d^3}{8} \cdot \int\limits_0^1 \rho d\rho \int\limits_0^{2\cdot\pi} d\varphi \int\limits_{\frac{\sqrt{1-\rho^2}}{2}}^{1} \delta(r,u)\,du =$$

$$= -\frac{\Delta(r) \cdot d^3 \cdot cos(\alpha(r))}{6}. \quad (6)$$

From (5) and (6) we can see that the basic property of a charge $Q_+(r) = -Q_-(r)$ of considered model of a proton is carried out at any distance r between electron and a proton. From (5) follows, that $Q_+(r) = Q_0(r) \cdot cos(\alpha(r))$, where

$$Q_0(r) = 6 \cdot \Delta(r) \cdot d^3. \quad (7)$$

Let's present $Q_0(r)$ as product of number of particles $N(r)$ and value of an elementary positive charge q, from (8) we find $\Delta(r)$:

$$\Delta(r) = \frac{N(r) \cdot q}{6 \cdot d^3}. \quad (8)$$

Having entered dimensionless value of distance ro, we shall present r also unknown functions N, f, α as:

$$r = ro \cdot d,$$

$$N(p,ro) = \frac{p_1 + p_2 \cdot ro^{p_3} + p_4 \cdot ro^{p_5} + p_6 \cdot ro^{p_7} + p_8 \cdot ro^{p_9}}{(1 + p_{10} \cdot ro^{p_{11}} + p_{12} \cdot ro^{p_{13}}) \cdot ro^{p_{14}}},$$

$$f(p,ro) = 1 + \frac{p_{15} + p_{16} \cdot ro^{p_{17}}}{(1 + p_{18} \cdot ro^{p_{19}}) \cdot ro^{p_{20}}}, \alpha(p,ro) = p_{21} \cdot ro, \quad (9)$$

where p_i, $i = (1,2,...,15)$ are elements of a vector p unknown parameters of model.

Energy of coulomb interaction $W(r)$ of electron with charges of a proton is equal:

$$W(r) = W_q(r) + W_\delta(r), \quad (10)$$

where (see also fig. 1)

$$W_q(r) = -\frac{q^2}{4 \cdot \pi \cdot \varepsilon_0 \cdot r}, \quad (11)$$

$$W_\delta(r) = -\frac{q}{4 \cdot \pi \cdot \varepsilon_0} \cdot$$

$$\int\limits_0^1 \frac{d^3}{8} \cdot \rho d\rho \int\limits_0^{2\cdot\pi} d\varphi \int\limits_{-\sqrt{1-\rho^2}}^{\sqrt{1-\rho^2}} \frac{\delta(r,u)}{MN} du =$$

$$= -\int\limits_0^1 \frac{d^3}{8} \cdot \rho d\rho \int\limits_0^{2\cdot\pi} d\varphi \int\limits_{-\sqrt{1-\rho^2}}^{\sqrt{1-\rho^2}} \cdot$$

$$\cdot \frac{2 \cdot \sqrt{f(r)} \cdot \delta(r,u)}{\sqrt{d^2 \cdot \rho^2 + f(r)^3 \cdot d^2 \cdot u^2 - 4 \cdot f(r)^2 \cdot d \cdot u \cdot r + 4 \cdot f(r) \cdot r^2}} du, \quad (12)$$

here: $W_q(r)$ is energy of interaction between electron and a positron (between electron and a proton in the standard model of hydrogen atom);

$W_\delta(r)$ is energy of interaction of electron with the distributed charge of a proton;

q is a positive elementary charge; ε_0 is an electric constant.

Using (8), , (12) we shall receive a ratio for energy of interaction $W(ro)$ (in eV) as

$$W(ro) = -\frac{q}{4 \cdot \pi \cdot \varepsilon_0 \cdot d} \cdot$$

$$\cdot \left(\frac{1}{ro} + 3 \cdot \pi \cdot N(p,ro) \cdot \sqrt{f(p,ro)} \cdot int(p,ro)\right), \quad (13)$$

where

$$int(p,ro) =$$

$$= \int\limits_0^1 \int\limits_{-\sqrt{1-\rho^2}}^{\sqrt{1-\rho^2}} \frac{cos\left(\frac{\pi \cdot u}{\sqrt{1-\rho^2}} + \alpha(p,ro)\right) \cdot \rho \cdot du \cdot d\rho}{\sqrt{\rho^2 + f(p,ro) \cdot (f(p,ro) \cdot u - 2 \cdot ro)^2}}. \quad (14)$$

The technique of a finding of parameters of model of hydrogen atom, calculation of its spectrum, calculation of diameter of a free proton are in detail described in work [2] (all calculations and the diagram are carried out in MATLAB environment). As the integral

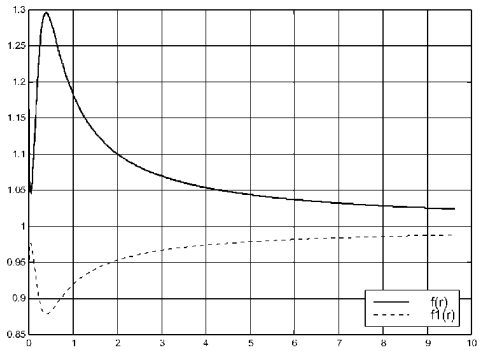

Figure 2: Diagram of functions $f1(r)$ and $f(r)$

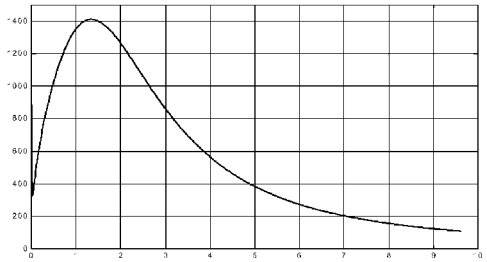

Figure 3: Diagram of function $N(r)$

(14) neither on ρ, nor on u analytically does not undertake also functions of numerical integration of double integral of the given type in MATLAB environment is not present, the program for calculation of integral $int(p, ro)$ has been created. At preset values p, ro value of the integral calculated in various environments is equal: in MAPLE is $2.741535 \cdot 10^{-6}$, in MATHCAD is $2.741538 \cdot 10^{-6}$ and in MATLAB (at splitting intervals integration on 90 parts) is $2.739701 \cdot 10^{-6}$.

As a result of nonlinear optimization (on three spectral lines of a series of Lajman) values of parameters of model p and d a free proton have made diameter: $p_1 = 2970.408$; $p_2 = 12.72109$; $p_3 = 1.878609$; $p_4 = 0.00201135$; $p_5 = 2.899783$; $p_6 = 211.8961$; $p_7 = 1.886657$; $p_8 = 38.12862$; $p_9 = 2.516716$; $p_{10} = 2.636954$; $p_{11} = -1.084322$; $p_{12} = 4.67143 \cdot 10^{-8}$; $p_{13} = 2.636954$; $p_{14} = 1.878609$; $p_{15} = 0.213009$; $p_{16} = 1.983586 \cdot 10^{-4}$; $p_{17} = 2.619292$; $p_{18} = 6.704616 \cdot 10^{-6}$; $p_{19} = 2.739018$; $p_{20} = 0.794056$; $p_{21} = 0.035$; $d = 4.01 \cdot 10^{-12} m$.

Diagram of functions $f1(r)$ and $f(r)$ which take into account change of the geometrical sizes of a proton at polarization are submitted on fig. 2.

On fig. 3 the diagram of the function $N(r)$ describing change of quantity electron-positron pairs at polarization of a proton is submitted.

We can see from diagrams fig. 2 and fig. 3 maximal number electron-positron pairs participating in polarization, the maximal value of function $f(r)$ and the

Table 1: Experimental and design values of a spectrum of hydrogen atom. Sign "*" mark the lines of a spectrum on which optimization were carried out.

topic	right	center	left
J	$\lambda 0_{j,1}$, nm	$\lambda_{j,1}$, nm	$\delta\lambda_{j,1}$, %
2*	121.5670	121.5661	$-9.36 \cdot 10^{-4}$
3*	102.5720	102.5722	$3.90 \cdot 10^{-5}$
4*	97.2537	97.2518	$-1.95 \cdot 10^{-3}$
5	94.9743	95.1235	$1.57 \cdot 10^{-1}$
6	93.7803	94.0804	$3.20 \cdot 10^{-1}$
7	93.0748	93.4844	$4.40 \cdot 10^{-1}$
8	92.6226	93.1024	$5.18 \cdot 10^{-1}$
9	92.3150	92.8363	$5.65 \cdot 10^{-1}$
10	92.0963	92.6393	$5.90 \cdot 10^{-1}$
11	91.9352	92.4868	$6.00 \cdot 10^{-1}$
12	91.8129	92.3647	$6.01 \cdot 10^{-1}$
13	91.7181	92.2646	$5.96 \cdot 10^{-1}$
14	91.6429	92.1807	$5.87 \cdot 10^{-1}$
15	91.5824	92.1093	$5.75 \cdot 10^{-1}$

minimal value of function $f1(r)$ are accordingly equal:

$$Nmax = 1413, \ fmax = 1.296, \ f1min = 0.878.$$

The difference between mass electron-positron pairs which are in a free condition, and mass created of them a proton makes mass defect of a proton Δm. Presence of a proton mass defect directly defines its stability which is characterized by binding energy:

$W = \Delta m \cdot c^2 = (2 \cdot Nmax \cdot m_e - m_p) \cdot c^2$, where m_e is mass of electron; m_p is mass of a proton; c is light speed.

As $m_p = 1836 \cdot m_e$ and $m_e \cdot c^2 = 0.511 Mev$ the estimation of binding energy of a proton gives value 506 Mev.

Design $\lambda_{j,1}$ and experimental $\lambda 0_{j,1}$ values of spectral lines of a series of Lajman, and also their relative deviate are submitted in the table. As we can see the experimental and design spectra differ on absolute size in limits from $3.9 \cdot 10^{-5}$% up to $1.95 \cdot 10^{-3}$% for the lines participating in optimization, and in limits from $1.57 \cdot 10^{-1}$% up to $6.01 \cdot 10^{-1}$% for the lines which are not participating in optimization.

On fig. 4 diagrams of energy $W(r)$ and $Wq(r)$ the coulomb interaction of electron according to a charge of a nucleus of considered model of hydrogen atom and a proton of the standard model are submitted.

We can see from fig. 4, the essential circumstance is that in considered model energy of interaction $W(r)$ at $r > 0.5$ nm is described by the continuous curve reminding fading fluctuations, and at $r < 0.5$ nm, accepting positive value, continuously grows at approach of electron borders of a proton. The last speaks that, since $r < 0.5$ nm, between electron and a proton there is only a force of pushing away which interferes with

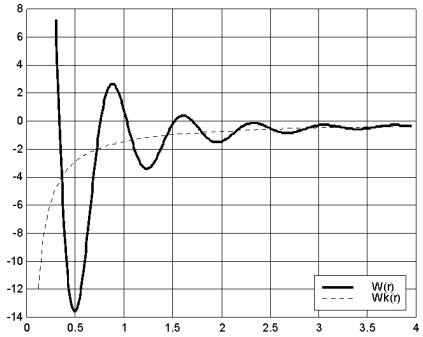

Figure 4: The diagram of energy of interaction of electron with a proton

the further approachment of electron with a proton. As have shown calculations, a power barrier to electron on border with a proton, i.e. at distance $r = 2,6 \cdot 10^{-12}$ is equal 0.367 Mev. The received results testify that the polarizing model of hydrogen atom is all-sufficient.

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FRAUDS IN 20-ST CENTURY PHYSICS

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Wrong statements (which become true frauds) on standard electrodynamics are stressed under the light of experimental physics. Classical field theory deserves to be thoroughly re-formulated. "Fixed field" assumptions are nonsense. Inductive electrodynamics phenomena depend on the state of motion of the field source.

"There is no relativity of rotation... We must sure to use equations of electromagnetism only with respect to inertial coordinate frames", R.P. Feymnan wrote in his popular "Lectures on Physics" [1],

Moreover, we can read, on page 144 of the widespread treatise [2] due to Panofshy and Phillips (hereafter PP):

It is necessary to use considerable care in extending the law of induction to take account of motion in general. We must first derive the subsidiary theorem which expresses the total time rate of change of the flux across a given surface in terms of a surface integral of the vector function B, even when the surface itself across which the flux is evaluated is in motionWe are seeking the function DB/Dt, defined by

$$d/dt\Phi_m = d/dt \int B \bullet dS = \int (DB/Dt) \bullet dS \qquad (1)$$

On page 149 remark PP:

"Whether the source of B is stationary or is in motion is entirely irrelevant, since any observed phenomena which depend on a field description must be describable in terms of the behavior of the field quantities alone, independent of the nature of the mechanism which produces the field quantities".

Let us consider the radial unipolar generator sketched in Fig.1a. The metallic probe is free to rotate sliding on a stationary ad hoc shaped conducting wire (hereafter the closing-wire) touching the probe at its ends. The above arrangement is located on the North pole of a uniform permanent magnet which produces a $B(r)$-field. The magnet remains stationary in the lab. As it is evident, dB/dt remains identically null on each charge located in the bulk of the wire, which means that Eq. (1) deserves to be carefully reexamined from a physical viewpoint.

We need to interpret Eq. (1) in a way consistent with the actual topology. We choose the surface element $d^2S = (r\omega dt)(dr)$, in order to ensure the constancy in time of $B(r)$ inside the considered differential domain (Fig.1b). After integrating on time we get $dS = (r\omega t dr)$, Labeling as $B_n(r)$ the component of $B(r)$ perpendicular to the plane of motion, Eq. (1) becomes

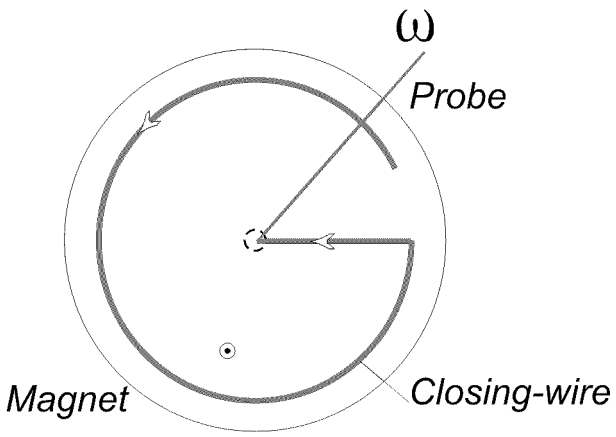

Figure 1: a The relevant features of unipolar induction

$$d/dt \iint B(r) \bullet d^2S = \int B(r) \bullet d(dS)/dt =$$

$$= \int B_n(r)\,\omega r dr = \omega < rB_n(r) > r$$

where $<>$ means average on the $(0, r)$ segment, and ω means angular rotational velocity. Only if $B_n(r) = B_0 = const$, then $< rB_n(r) >= B_0 < r >= B_0(r/2)$, and Eq.(1) recovers its familiar form $d/dt \iint B(r) \bullet d^2S = (\omega B_0 r^2)/2$.

Since $emf = -d/dt\Phi_m$ we get $\int (B_n \omega r) \bullet dr = \oint E \bullet dI$, from which follows $E = B_n \omega r$.

Starting from Faraday's law, we were able to recover Lorentz's force expression, $F_L = qE = q(u \times B)$ acting on each moving charge q, since $u = \omega \times r$ measures the velocity of the charge located at r, with respect to the lab.

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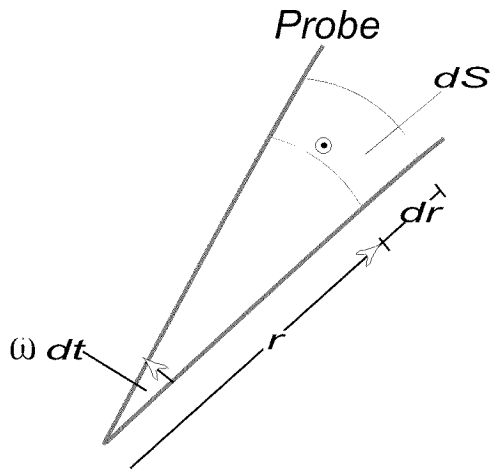

Figure 2: b Differential surface available for calculations

Magnetic flux linking the circuit diminishes in time in figure 1. The direct current J generated has also the counterclockwise sense, in full accordance with Lenz's rule.

Recent experiments grant the full motional symmetry of unipolar induction [3]. Let us consider the probe stationary in the lab whereas the magnet (with the closing-wire attached to it) is spun at - ω (clockwise rotation in the figure 1.a). In this case the same Lorentz-type induced field E does appear on the stationary probe. The wires attached to the magnet only play a passive role: to provide a current path.

The above experimental output means that the considered phenomenon is governed by the motion of the probe relative to the magnet, but no the absolute motion of the probe as mistakenly believed up today [1,2,4].

Also Lorentz's force gains a deep meaning since it can be expressed as

$$F_L = q\,(u \times B) = q\left[(\omega_{probe} - \omega_{magnet})\,\hat{k} \times r\right] \times B\,,$$

u being the velocity of the probe's charge located at r, and $\hat{k}$ labeling the unit vector perpendicular to the plane of motion. In case the closing wire is not attached to the magnet, so that magnet and probe can move together while the closing wire stays at rest in the lab, the radial portion of the latter becomes the seat of the electromotive force (emf), thus interchanging roles with the probe. In both cases it is relative motion between the magnet and a radial wire of the sensing circuit that generates the observed emf. The wires attached to magnet only play a passive role: to provide a current path.

We cannot refrain from quoting Einstein when referring to the electrodynamics of moving bodies, at the beginning of his famous 1905 paper [5]:

It is known that Maxwell's electrodynamics (as usually understood at the present time) when applied to moving bodies, leads to asymmetries which do not appear to be inherent in the phenomena".

Regrettably, Einstein himself was misinterpreted for his followers when dealing with electrodynamical motional symmetries!

Also Weber was able to formulate a fully relativistic theory of electrodynamics entirely free of such apparent asymmetries [6]. Unipolar induction can be explained within the realm of Weber's rationale [7].

Applied electrodynamics entails some subtleties, and a thorough physical re-interpretation of its fundamental equations appears to be necessary in order to improve the understanding of current and new phenomena. There is a growing interest in the search for an invariant neo-Hertzian formulation of Maxwell's equations stressing the relevance of the Galilean invariant operator $d/dt = \partial/\partial t + (V_d \bullet \nabla)$, V_0 being the field detector velocity [8, 9]. In fact, infertility has nothing to do with electromagnetic induction [10]. We don't need Lorentz's transformation in order to grasp the relevant phenomena, and we are compelled to go towards a genuine relativity.

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TESTING $qv = I\Delta L$ FOR ELECTROLYTIC CURRENTS

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The relation $qv = I\Delta L$, advanced by Weber and Lorentz in order to get a microscopic interpretation to macroscopic ponderomotive forces acting on filamentary current carrying systems, was experimentally verified for ionic currents.

1. INTRODUCTION

When Maxwell wrote his masterful *"Treatise on Electricity and Magnetism"*, the discrete nature of the electric fluid (the electron itself) was yet unproven. When referring to the ponderomotive force due to currents or magnets, acting on current carrying wires (Laplace's force $F_{La} = I\,(\Delta I \times B)$, Maxwell stressed:

"It must be carefully remembered, that the mechanical force which urges a conductor carrying a current across the lines of magnetic force, acts not on the electric current, ***but on the conductor*** *which carries it. The only force which acts on electric currents is electromotive force"* [1].

Shortly after the discovery of the electron by Thomsom, Lorentz published his famous *"Theory of Electrons"*, in which his law of force $F_{Lo} = qv \times B$ does appear explicitly stated. Lorentz himself was able to *interpret* Laplace force in terms of his own law [2], via the substitution $qv = I\Delta L$. The modern rationale of electrodynamics takes as granted that the electrons responsible for metallic conduction are acted on by Lorentz' force and, via inelastic collisions with the crystalline lattice, are able to exchange linear momentum with the solid, giving rise to the ponderomotive Laplace's force. Also inelastic collisions would be responsible for the Joule heat dissipated when current flows. It is worthwhile to remember that Ampre was the man who introduced into physics the current element ($I\Delta L$) concept, as being the *particle* of electrodynamics. Weber was the first man able to interpret Ampre current element in terms of atomic particles. He envisaged current as being due to positively and negatively charged particles, moving across the conductor at equal velocity in opposite directions.

Maxwell's viewpoint has been recently advocated by Graneau, by stressing the role played by the metallic lattice: *"This means, ultimately, that Amperian current elements have to be atoms which have become magnetically polarized owing to the flow of electrons"* [3].

In order to throw light on the matter, we have devised a new class of experiments performed on electrolytic currents instead of electronic ones. The main advantages of our procedure are:

- To avoid quantum-mechanical complications arising from the intrinsic nature of electrons (quantized energy levels, Pauli's exclusion principle, Fermi work function)

- To avoid treating a crystalline lattice as an "unmovable" box for the Fermi electronic gas.

- To handle a system in which the energy equipartition theorem holds.

The idea was to replace ordinary metallic conductors with a plastic pipe, the *probe* from here on, containing a highly concentrated solution of a salt. The pipe, mechanically decoupled from the *closing circuit wire* [4], but electrically connected with a DC source via mercury cups, is located in a moderately strong magnetic field in order to search for mechanical actions.

2. EXPERIMENTAL

2.1. SETUP

A polyethylene ($0.5cm^2$ cross-section, *5 cm* length) cylinder (the probe) was filled with aqueous $NaNO_3$ concentrated solution. The cylinder was terminated as two platinum disks in order to get a uniform electric field on the electrolyte. Small platinum wires were welded to each disk, thus enabling electrical continuity through mercury (figure 1).

The electrical conductivity of the electrolytic solution (measured at 25 $°C$ with the aid of a commercial AC bridge) was as high as *146,500* $\mu S/cm$, which leads

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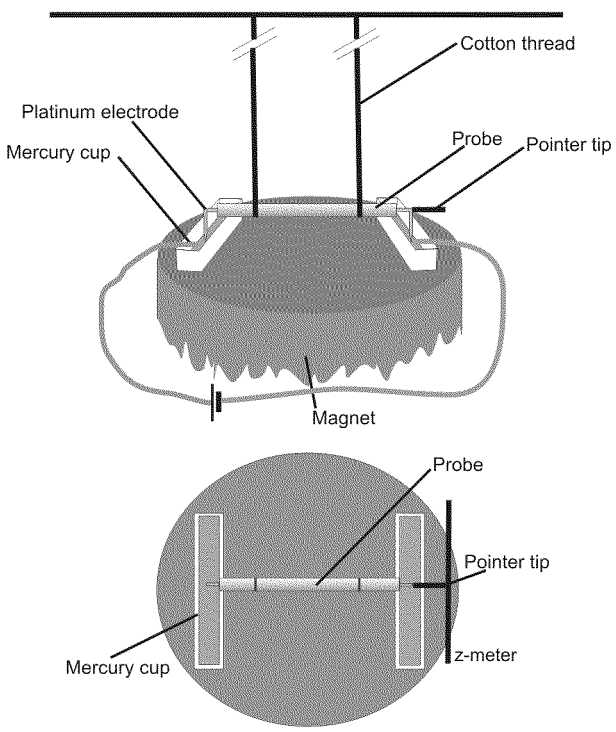

Figure 1: Experimental setup, frontal and top views

to the resistivity $\rho = 6.85\Omega cm$. The electrical resistance of our probe reached $6.85\,(5/0.5) = 68.5\Omega$. Probe's mass (*ca. 4g*) was adjusted up to $M = 4.000g$.

With the aid of cotton threads ($H = 0.3m$length), the probe was suspended from a wood support, becoming a pendulum available for force measurements. Beneath the probe, a (*15 cm* radius) rare-earth permanent magnet becomes the source of the static magnetic field B, which reaches some *1,000 gauss* ($0.1Wb/m^2$) on the probe itself (figure 1).

A current-controlled source allows us to inject DC in the probe through the (arbitrarily shaped) closing wire.

2.2. QUALITATIVE OBSERVATIONS

When DC amounting *ca. 1 A* is injected in the circuit, the probe vigorously moves departing from its equilibrium location. The sense of motion reverses when the current is reversed. The same occurs when reversing the magnet's pole beneath the probe. When current is doubled, also the probe's excursion is roughly doubled. No lateral motion was observed on the probe.

Joule heat on the probe becomes ostensible when current injection is prolonged. Also probe's resistance slightly changes with time, a fact which compels the source to correct its output voltage in order to maintain a constant current in the whole circuit.

We get similar outputs when dealing with concentrated aqueous solutions of $NaCl$, CIH, $BaCl_2$ and SO_4H_2.

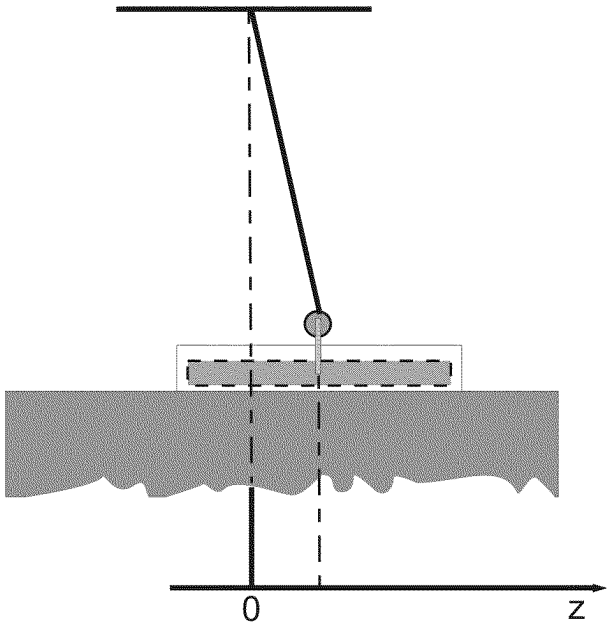

Figure 2: Testing-force pendulum

2.3. QUANTITATIVE MEASUREMENTS

Now we need to make some basic assumptions in order to rationalize the observed facts:

- The field acting on the probe is essentially along the magnet axis (radial components of B become negligible in the neighborhood of the magnet's pole).

- Interaction with Earth's magnetic field will be neglected in our experiments ($B_{earth}/B < 10^{-3}$).

- The axial component of the field B remains roughly constant on the probe.

- The observed forces are in compliance with Laplace's law, which now reads $F_{La} = ILB$.

- Gravitational force on the probe counteracts Laplace's force at equilibrium: $Mg.sin\alpha = ILB$, which becomes $Mg\,(z/H) = ILB$, for small angular displacements. Here z labels probe's horizontal linear displacement from its equilibrium position (i.e. without current injection) and H is the pendulum length (figure 2). We wish to check the equation

$$z = (LBH/Mg)\,.I = A.I \tag{1}$$

in order to verify Laplace's force.

- Current injection is made as fast as possible in order to avoid spurious effects which will be later on considered.

Taking $g = 9.8ms^{-2}$ we get

$$A \equiv LBH/Mg \approx 3.8 \times 10^{-2}m/A = 3.8cm/A$$

for our actual setup ($L = 0.05 \pm 0.001m$, $B = 0.1 \pm 0.01Wb/m^2$, $H = 0.300 \pm 0.002m$, $M = 0.004 \pm$

Table 1: The output of a typical experimental run

$I\,(A)$	$+z\,(cm)$
0.1	0.40
0.2	0.75
0.3	1.20
0.4	1.60
0.5	1.85
0.6	2.15
0.7	2.55
0.8	2.95
0.9	3.20
1.0	3.65

Table 2: Another output of a typical experimental run

$I\,(A)$	$-z\,(cm)$
0.1	0.35
0.2	0.80
0.3	1.10
0.4	1.55
0.5	1.95
0.6	—
0.7	—
0.8	—
0.9	—
1.0	3.50

$0.00001kg$. Probe linear displacement z was measured with the aid of a micrometer anchored to the desk. One of the wires connecting the probe with its respective mercury cup was taken as the sensing-displacement pointer tip, and the experimental uncertainty was as high as $\pm 0.05cm$. The experimental uncertainty in current was less than $\pm 0.02A$ in the (0, 0.4) range and less than $\pm 0.05A$ in the (0.4, 1.0) range.

Table 1 gives the output of a typical experimental run

Another run in which current was reversed (which means $z < 0$) leads to

Adjusting the above pairs according to least squares we get (graph 1)

$$z = 3.6I + 0.007 \cong 3.6I.$$

From the above measurements we conclude that equ.(1) is valid within the experimental uncertainty.

2.4. OPERATIVE CAUTIONS

Ionic (electrolytic) current is quite different from an electronic one. In our actual setup the current carriers are the ions Na^+ and NO_3^-. Acted on by the electromotive force impressed from the external DC source, Na^+ moves toward the negative electrode (cathode), whereas NO_3^- moves to the positive one (anode). At

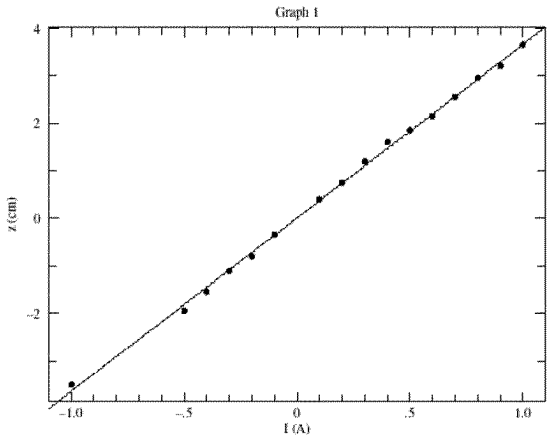

Figure 3: A typical experimental run

the interface aqueous solution/electrode some chemical reactions, able to transfer electrons, take place in order to get electrical continuity with the source, via the circuit closing wire. Thus, at the cathode there occurs liberation of gaseous hydrogen coming from water:

$$2H^+ + 2e^- = H_2.$$

It is said that hydrogen becomes *reduced*, taking electrons from the cathode. Such electrons must be injected at the anode through another chemical reaction such as oxygen discharge:

$$2OH^- = H_2O + \tfrac{1}{2}O_2 + 2e^-.$$

The two above reactions are possible thanks to the water ionic equilibrium: $H_2O = H^+ + OH^-$. Also the chemical transformation of NO_3^- can take place near the anode, a fact irrelevant for our actual purposes.

The whole phenomenon is known as *electrolysis* and, if very prolonged, induces ostensible changes in electrolyte concentration near the electrodes. The above produces departures from Ohm's law.

Delivered gases partially cover the electrode surfaces (sorption), disturbing the normal electronic transference at the solution/electrode interface, thus increasing the ohmic resistance on the probe. The phenomenon is known as *polarization* [5, 6].

Joule heat delivered at the probe diminishes fluid viscosity, which is reflected as an increase in the ionic mobilities: unlike electronic conduction, ionic conduction is thermally enhanced. For a DC amounting to *1A*, *ca. 70 W* are dissipated as heat at the probe in our actual setup.

Taking into account all the above considerations, measurements must be performed as quickly as possible.

3. THEORETICAL CONSIDERATIONS

Electrolytic (ionic) conduction can be understood in terms of the partial conductivities due to the various types of ions present [5, 6]. Each partial conductivity depends on the *ionic velocities* v_+, v_-, and on the ionic *concentration* n_+, n_-, (number of ions per unit volume). Thus, current density J can be expressed as

$$J = \left(n_+\nu^+ v_+ + n_-\nu^- v_-\right) e = \sigma E, \tag{2}$$

wherein ν means the ionic valence (1 for Na^+ and NO_3) and e labels the electronic charge. On account of the electrical neutrality ($n_+\nu^+ = n_-\nu^-$), equ.2 becomes

$$J = n_+\nu^+ .e\left(v_+ + v_-\right). \tag{3}$$

Each ion is urged by two opposite forces: the electric one, νeE, and the braking force, f_b due to viscosity. Assuming a spherical symmetry for the ion we get, with the aid of Stokes hypothesis, $f_b = 6\pi rv$ (r being ion's radius and η the viscosity coefficient). When current attains its steady state it will be $\nu eE = 6\pi\eta rv$, from which follows $u \equiv v/E = \nu e/6\pi\eta r$, a quantity known as *ionic mobility* (transport velocity of the ion per unit applied electric field). With the above considerations, equ.3 becomes $\sigma = n_+\nu^+ .e\left(u_+ + u_-\right)$. For most ions at ordinary temperature, mobilities amount to some $50 \times 10^{-6} cm^2/V.s$ [6].

In some sense, electrolytic conduction resembles the Weber-Fechner model for metallic (electronic) conduction [7]. Note that the velocities involved in equ.3 and in the braking force, are ionic velocities measured with respect to the fluid matrix (water) but no velocities referred to a hypothetical observer.

4. FINAL CONSIDERATIONS

The here reported experimentation ensures, beyond reasonable doubts, that the observable ponderomotive effects have their seat in the microscopic current-carriers (the ions itself). A crystalline lattice is absent in aqueous solutions, which prevents speculations on possible *polarization* of the current elements [3] due to the magnetic field. Neither can quantum-mechanical constraints be invoked, since the analyzed system exhibits a classical behavior. The basic tenet involved in $qv = I\Delta L$ works in ionic conductors: ponderomotive force acts on each moving particle. Via inelastic collisions, ions do transfer linear momentum to the surrounding fluid, which also transfers momentum to the dielectric envelope (the pipe itself) giving rise to the observed Laplace's force. Since the force of a closed circuit on a current element of another circuit is the same for both Ampre-Weber and Grassmann-Lorentz rationale [7], our experimental observations only ensures the goodness of the $qv = I\Delta L$ hypothesis.

Electrolyitic currents can help to solve an old controversy in electrodynamics, such as the existence of longitudinal ponderomotive forces in conductors, predicted by Ampre but neglected in the Grassmann-Lorentz framework [3, 7].

Acknowledgements

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