LOW ENERGY NUCLEAR REACTIONS: ENERGY FROM FROM A DYNAMIC FRAME OF REFERENCE IN ECE THEORY.

by

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ABSTRACT

It is shown that the tetrad of Cartan's differential geometry may be expressed as a mixed index metric, the upper or a index of which introduces the concept of energy from geometry, representing spacetime. In low energy nuclear reactions (LENR) this energy is transferred to the reaction and makes possible the quantum tunnelling of one atom into another, resulting in nuclear fusion. The Einstein energy equation of special relativity is developed into an equation of general relativity using this concept of energy from geometry. In special relativity the frame is static, in general relativity it is dynamic.

Keywords: Low energy nuclear reaction, ECE theory, energy form a moving frame, Cartan tetrad as a mixed index metric.

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1. INTRODUCTION

In this series of two hundred and thirty one papers and books to date {1 - 10}, physics has been unified self consistently from the equations of differential geometry in Einstein Cartan Evans (ECE) theory. Recently ECE theory in its Schroedinger limit has been applied to reproducible and repeatable data on low energy nuclear reactions (LENR) {11, 12}. It was found that LENR occurs by quantum tunnelling with resonant absorption of energy quanta such as photons. Quantum tunnelling alone is not enough to cause the reaction to occur. In this paper the concept of energy from geometry is developed, geometry being a representation of spacetime and frame of reference. In order to demonstrate this idea the most clearly, the original idea of the tetrad, introduced by Cartan, is developed into a mixed index metric. Cartan's original intention was to define his earlier concept of spinor in general relativity by introducing a Minkowski spacetime tangent at P to the base manifold. At the outset of ECE theory in 2003 this idea was generalized. The tetrad was defined as the relation between two coordinate systems labelled a and μ in the same mathematical space. For example a can be the index of the complex circular basis and μ the index of the Cartesian basis. In Section 2 it is shown that this concept leads to the definition of the tetrad as a mixed index metric which can be expressed as the dot product of two unit vectors, one indexed a, one indexed μ. This definition also holds for Cartan's original analysis. The frame indexed μ is static, but the frame indexed a can be made a dynamic frame through the introduction of a phase that depends both on angular frequency and wavenumber. It follows that the Cartan torsion and curvature are defined entirely in terms of the dynamic unit vector, and that this vector is the source of energy from geometry. In ECE theory, the a index is the one responsible for transforming the static four potential of electrodynamics for example into the dynamic four potential of electrodynamics, or the static four potential of gravitation into the dynamic four potential of gravitation.

Section 3 applies these basic definitions to the energy momentum four vector to give the Einstein energy equation in general relativity. The dynamics of the moving frame defined by the index a introduces a source of energy not present in the original Einstein energy equation of special relativity, defined by the static Minkowski frame. This source of energy is referred to as energy from geometry, or energy from spacetime, and is based on the fundamental idea of general relativity, the infinitesimal line element or metric, the tetrad now taking the role of metric. The Einstein energy equation of general relativity exists in a spacetime with non zero torsion and curvature, that of special relativity exists in a spacetime without torsion and curvature. So torsion and curvature are derived as usual from the Cartan structure equations using the spin connection, but the mathematics are controlled entirely now by the dynamics of the unit vector $\underline{e}^a$. The transformation of the Einstein energy equation from one of special to general relativity is defined as a frame transformation in spacetime in which the rest energy mc^2 is assumed to be an invariable of the transformation. These new concepts are quantized by defining the Schroedinger postulate for partial derivatives of index a. The frame transformation is developed in terms of a minimal prescription, the new source of energy being defined as the potential energy of the minimal prescription. The Schroedinger limit is defined, and the transmission coefficient of quantum tunnelling computed using this potential in Section 4.

2. DEFINITION OF THE TETRAD AS A MIXED INDEX METRIC.

Consider the general definition of the Cartan tetrad {1 - 10}

$$V^a = q^a_\mu V^\mu \qquad -(1)$$

where V^a indicates the components of a vector indexed a, and V^μ indicates the components of the same vector indexed μ. Written out in full Eq. (1) is a matrix equation. For simplicity of illustration consider the transverse components, so:

$$\begin{bmatrix} V^{(1)} \\ V^{(2)} \end{bmatrix} = \begin{bmatrix} q^{(1)}_{1} & q^{(1)}_{2} \\ q^{(2)}_{1} & q^{(2)}_{2} \end{bmatrix} \begin{bmatrix} V^{1} \\ V^{2} \end{bmatrix} = \begin{bmatrix} q^{(1)}_{1} V^{1} + q^{(1)}_{2} V^{2} \\ q^{(2)}_{1} V^{1} + q^{(2)}_{2} V^{2} \end{bmatrix} . \quad -(2)$$

It is seen that there is summation over the repeated μ indices. This summation convention is equivalent to matrix algebra. The μ index of the tetrad is raised using the inverse metric as follows:

$$q^{a\nu} = q^{a}_{\mu} g^{\mu\nu} = \begin{bmatrix} q^{(1)}_{1} & q^{(1)}_{2} \\ q^{(2)}_{1} & q^{(2)}_{2} \end{bmatrix} \begin{bmatrix} g^{11} & g^{12} \\ g^{21} & g^{22} \end{bmatrix} = \begin{bmatrix} q^{(1)}_{1} g^{11} + q^{(1)}_{2} g^{21} & q^{(1)}_{1} g^{12} + q^{(1)}_{2} g^{22} \\ q^{(2)}_{1} g^{11} + q^{(2)}_{2} g^{21} & q^{(2)}_{1} g^{12} + q^{(2)}_{2} g^{22} \end{bmatrix} \quad -(3)$$

and in each of the four matrix elements there is summation over the repeated index. Next consider:

$$q^{a\nu} g_{\mu\nu} = q^{a}_{\mu} g^{\mu\nu} g_{\mu\nu} . \quad -(4)$$

It can be proven as follows that:

$$\left(q^{a}_{\mu} g^{\mu\nu} \right) g_{\mu\nu} = q^{a}_{\mu} \left(g^{\mu\nu} g_{\mu\nu} \right) \quad -(5)$$

which is an example of matrix algebra. The left hand side of Eq. (5) is:

$$\begin{bmatrix} q^{(1)}_{1} g^{11} + q^{(1)}_{2} g^{21} & q^{(1)}_{1} g^{12} + q^{(1)}_{2} g^{22} \\ q^{(2)}_{1} g^{11} + q^{(2)}_{2} g^{21} & q^{(2)}_{1} g^{12} + q^{(2)}_{2} g^{22} \end{bmatrix} \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix}$$

$$= \begin{bmatrix} q^{(1)}_{1} g^{11} g_{11} + q^{(1)}_{2} g^{21} g_{11} + q^{(1)}_{1} g^{12} g_{21} + q^{(1)}_{2} g^{22} g_{21} & \cdots \\ \cdots & \cdots \end{bmatrix} \quad -(6)$$

and the right hand side is:

$$\begin{bmatrix} q^{(1)}_1 & q^{(1)}_2 \\ q^{(2)}_1 & q^{(2)}_2 \end{bmatrix} \left(\begin{bmatrix} g^{11} & g^{12} \\ g^{21} & g^{22} \end{bmatrix} \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix} \right)$$

$$= \begin{bmatrix} q^{(1)}_1 & q^{(1)}_2 \\ q^{(2)}_1 & q^{(2)}_2 \end{bmatrix} \begin{bmatrix} g^{11} g_{11} + g^{12} g_{21} & g^{11} g_{12} + g^{12} g_{22} \\ g^{21} g_{11} + g^{22} g_{21} & g^{21} g_{12} + g^{22} g_{22} \end{bmatrix}$$

$$= \begin{bmatrix} q^{(1)}_1 g^{11} g_{11} + q^{(1)}_1 g^{12} g_{21} + q^{(1)}_2 g^{21} g_{11} + q^{(1)}_2 g^{22} g_{21} & \cdots \\ \cdots & \cdots \end{bmatrix} \quad -(7)$$

so Eq. (5) is proven, Q. E. D.

In this notation $g_{\mu\nu}$ denotes the metric and $g^{\mu\nu}$ denotes the inverse metric. So by definition:

$$g^{\mu\nu} g_{\mu\nu} = 1, \quad -(8)$$

$$g^{a\nu} = q^{a\nu} = q^a_\mu g^{\mu\nu}. \quad -(8a)$$

Multiply both sides of Eq. (8a) by $g_{\mu\nu}$:

$$g^{a\nu} g_{\mu\nu} = q^a_\mu \left(g^{\mu\nu} g_{\mu\nu} \right) = q^a_\mu \quad -(9)$$

to give the required definition of the tetrad as a mixed index metric:

$$q^a_\mu = g^a_\mu = g^{a\nu} g_{\mu\nu}. \quad -(10)$$

When μ and ν label the flat and static Minkowski spacetime:

$$g_{\mu\nu} = g^{\mu\nu} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix} \quad -(11)$$

then:

$$g^{a\nu} = \begin{bmatrix} g^{(0)0} & g^{(0)1} & g^{(0)2} & g^{(0)3} \\ g^{(1)0} & g^{(1)1} & g^{(1)2} & g^{(1)3} \\ g^{(2)0} & g^{(2)1} & g^{(2)2} & g^{(2)3} \\ g^{(3)0} & g^{(3)1} & g^{(3)2} & g^{(3)3} \end{bmatrix} \quad -(12)$$

and:

$$V^{a}_{\mu} = g^{a}_{\mu} = \begin{bmatrix} g^{(0)}_{0} & g^{(0)}_{1} & g^{(0)}_{2} & g^{(0)}_{3} \\ g^{(1)}_{0} & g^{(1)}_{1} & g^{(1)}_{2} & g^{(1)}_{3} \\ g^{(2)}_{0} & g^{(2)}_{1} & g^{(2)}_{2} & g^{(2)}_{3} \\ g^{(3)}_{0} & g^{(3)}_{1} & g^{(3)}_{2} & g^{(3)}_{3} \end{bmatrix} \quad -(13)$$

$$= \begin{bmatrix} g^{(0)0} & -g^{(0)1} & -g^{(0)2} & -g^{(0)3} \\ g^{(1)0} & -g^{(1)1} & -g^{(1)2} & -g^{(1)3} \\ g^{(2)0} & -g^{(2)1} & -g^{(2)2} & -g^{(2)3} \\ g^{(3)0} & -g^{(3)1} & -g^{(3)2} & -g^{(3)3} \end{bmatrix}.$$

In general:

$$g^{a\nu} = h^{a} h^{\nu} \, \underline{e}^{a} \cdot \underline{e}^{\nu} \quad -(14)$$

where the scale factors are defined by:

$$h^{a} = |\underline{e}^{a}|, \; h^{\nu} = |\underline{e}^{\nu}|. \quad -(15)$$

Similarly:

$$q^a_\mu = \gamma^a_\mu = h^a h_\mu \, \underline{e}^a \cdot \underline{e}_\mu, \quad -(16)$$

$$h^a = |\underline{e}^a|, \; h_\mu = |\underline{e}_\mu|. \quad -(17)$$

In Minkowski spacetime the contravariant unit vector is:

$$\underline{e}^\mu = (1, \underline{i}, \underline{j}, \underline{k}) \quad -(18)$$

and in the spacetime labelled conveniently by (a):

$$\underline{e}^{(a)} = (1, \underline{e}^{(1)}, \underline{e}^{(2)}, \underline{e}^{(3)}). \quad -(19)$$

Therefore the covariant unit vector is:

$$\underline{e}_\mu = (1, -\underline{i}, -\underline{j}, -\underline{k}) \quad -(20).$$

with:

$$|\underline{i}| = |\underline{j}| = |\underline{k}| = 1, \quad -(21)$$

$$h^0 = h^1 = h^2 = h^3 = 1.$$

If the a basis is chosen with unit scaling factors then:

$$q^a_\mu = \gamma^a_\mu = \underline{e}^a \cdot \underline{e}_\mu. \quad -(22)$$

This is a fundamental definition of the tetrad that may be used throughout differential geometry. Similarly the tetrad with raised index is:

$$q^{a\mu} = \gamma^{a\mu} = \underline{e}^a \cdot \underline{e}^\mu. \quad -(23)$$

The electromagnetic potential of ECE theory may now be defined {1 - 10}:

$$A^a_\mu = \underline{e}^a \cdot \underline{A}_\mu \quad -(24)$$

or with raised μ index:

$$A^{a\mu} = \underline{e}^{(a)} \cdot \underline{A}^{\mu}. \quad -(25)$$

In general:

$$\underline{A}^{\mu} = \left(A^0, A_x \underline{i}, A_Y \underline{j}, A_Z \underline{k}\right) \quad -(26)$$

and the static unit vector $\underline{e}^{(a)}$ is:

$$\underline{e}^{(a)} = \left(\underline{1}, \underline{e}^{(1)}, \underline{e}^{(2)}, \underline{e}^{(3)}\right). \quad -(27)$$

The dynamic unit vector $\underline{e}^{(a)}$ is defined with the transformation:

$$\underline{e}^{(a)} = \left(\underline{1}, \underline{e}^{(1)} e^{i\phi}, \underline{e}^{(2)} e^{-i\phi}, \underline{e}^{(3)}\right) \quad -(28)$$

where the phase is:

$$\phi = \omega t - \kappa Z \quad -(29)$$

Here ω is the angular frequency at instant t, and κ the wave vector magnitude at Z.

By defining the electromagnetic potential as a mixed index metric in this way, the tetrad postulate becomes identical with the metric compatibility condition, and the spin connection can be defined from the tetrad postulate. The Cartan structure equations are used with the spin connection to define the torsion and curvature, which are linked by the Cartan identity. The whole of this process has been subsumed into the dynamics of the vector $\underline{e}^{(a)}$, thus giving a new understanding of differential geometry and unified physics.

3. EINSTEIN ENERGY EQUATION IN GENERAL RELATIVITY.

Consider the energy momentum four vector in the static Minkowski frame:

$$p^{\mu} = \left(\frac{E}{c}, \underline{p} \right) \quad -(30)$$

The contravariant and covariant components of the linear momentum are:

$$p^1 = p_X, \; p^2 = p_Y, \; p^3 = p_Z, \quad -(31)$$
$$p_1 = -p_X, \; p_2 = -p_Y, \; p_3 = -p_Z.$$

In the circular polar representation:

$$p^{(1)} = \frac{1}{\sqrt{2}}(p_X - i p_Y), \; p^{(2)} = \frac{1}{\sqrt{2}}(p_X + i p_Y), \quad -(32)$$
$$p_{(1)} = -\frac{1}{\sqrt{2}}(p_X - i p_Y), \; p_{(2)} = -\frac{1}{\sqrt{2}}(p_X + i p_Y).$$

so it follows that:

$$p^{(1)} p^{(2)} + p^{(2)} p^{(1)} = p_X^2 + p_Y^2 \quad -(33)$$

and:

$$p^{(1)} p_{(2)} + p^{(2)} p_{(1)} = -\left(p_X^2 + p_Y^2\right). \quad -(34)$$

In this notation the Einstein energy equation is:

$$p^0 p_0 + p^1 p_1 + p^2 p_2 + p^3 p_3 = m^2 c^2 \quad -(35)$$

or

$$p^{(0)} p_{(0)} + p^{(1)} p_{(2)} + p^{(2)} p_{(1)} + p^{(3)} p_{(3)} = m^2 c^2 \quad -(36)$$

The transformation to general relativity from special relativity is defined by:

$$p^{(1)} = \frac{1}{\sqrt{2}}\left(p_x - ip_y\right)e^{i\phi}, \quad -(37)$$
$$p^{(2)} = \frac{1}{\sqrt{2}}\left(p_x + ip_y\right)e^{-i\phi},$$

the covariant components of which are:

$$p_{(1)} = -\frac{1}{\sqrt{2}}\left(p_x - ip_y\right)e^{i\phi}, \quad -(38)$$
$$p_{(2)} = -\frac{1}{\sqrt{2}}\left(p_x + ip_y\right)e^{-i\phi}.$$

For two static frames labelled (a) and μ, it follows that:

$$p^2 = p_x^2 + p_y^2 + p_z^2 \quad -(39)$$
$$= \underline{p}^{(3)} \cdot \underline{p}^3 + \sqrt{2}\left(\underline{p}^{(1)} \cdot \underline{p}^1 - i\underline{p}^{(2)} \cdot \underline{p}^2\right).$$

and that the Einstein energy equation is:

$$E^2 - c^2p^2 = m^2c^4. \quad -(40)$$

When the frame labelled (a) is transformed into a dynamic frame using Eqs. (28) and (29) then

$$p^2 = \underline{p}^{(3)} \cdot \underline{p}^3 + \sqrt{2}\left(\underline{p}^{(1)} \cdot \underline{p}^1 e^{i\phi} - i\underline{p}^{(2)} \cdot \underline{p}^2 e^{-i\phi}\right)$$
$$= p_z^2 + p_x^2 e^{i\phi} + p_y^2 e^{-i\phi}. \quad -(41)$$

Denote:

$$\pi^2 = p_z^2 + p_x^2 e^{i\phi} + p_y^2 e^{-i\phi} \quad -(42)$$

and noting that the energy is also transformed:

$$E \rightarrow \epsilon \quad -(43)$$

it follows that:

$$\epsilon^2 - c^2\pi^2 = E^2 - c^2 p^2 = m^2 c^4 \quad -(44)$$

in which the rest energy mc^2 is an invariant of the frame transformation. Eq. (44) therefore denotes a Hamilton Jacobi transformation from special to general relativity.

The derivation of Eq. (44) can be checked from the basic definition:

$$\begin{bmatrix} \underline{e}^{(1)} \\ \underline{e}^{(2)} \end{bmatrix} = \begin{bmatrix} q_1^{(1)} & q_2^{(1)} \\ q_1^{(2)} & q_2^{(2)} \end{bmatrix} \begin{bmatrix} \underline{e}^1 \\ \underline{e}^2 \end{bmatrix} \quad -(45)$$

Multiply both sides of Eq. (45) by $\begin{bmatrix} \underline{e}_1 & \underline{e}_2 \end{bmatrix}$ from the right:

$$\begin{bmatrix} \underline{e}^{(1)} \\ \underline{e}^{(2)} \end{bmatrix} \cdot \begin{bmatrix} \underline{e}_1 & \underline{e}_2 \end{bmatrix} = \begin{bmatrix} q_1^{(1)} & q_2^{(1)} \\ q_1^{(2)} & q_2^{(2)} \end{bmatrix} \begin{bmatrix} \underline{e}^1 \\ \underline{e}^2 \end{bmatrix} \cdot \begin{bmatrix} \underline{e}_1 & \underline{e}_2 \end{bmatrix} \quad -(46)$$

so:

$$\begin{bmatrix} \underline{e}^{(1)} \cdot \underline{e}_1 & \underline{e}^{(1)} \cdot \underline{e}_2 \\ \underline{e}^{(2)} \cdot \underline{e}_1 & \underline{e}^{(2)} \cdot \underline{e}_2 \end{bmatrix} = \begin{bmatrix} q_1^{(1)} & q_2^{(1)} \\ q_1^{(2)} & q_2^{(2)} \end{bmatrix} \begin{bmatrix} \underline{e}^1 \cdot \underline{e}_1 & \underline{e}^1 \cdot \underline{e}_2 \\ \underline{e}^2 \cdot \underline{e}_1 & \underline{e}^2 \cdot \underline{e}_2 \end{bmatrix} . \quad -(47)$$

In the Cartesian basis for three dimensional space:

$$\begin{bmatrix} \underline{e}^1 \cdot \underline{e}_1 & \underline{e}^1 \cdot \underline{e}_2 \\ \underline{e}^2 \cdot \underline{e}_1 & \underline{e}^2 \cdot \underline{e}_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \quad -(48)$$

so:

$$\begin{bmatrix} q_1^{(1)} & q_2^{(1)} \\ q_1^{(2)} & q_2^{(2)} \end{bmatrix} = \begin{bmatrix} \underline{e}^{(1)} \cdot \underline{e}_1 & \underline{e}^{(1)} \cdot \underline{e}_2 \\ \underline{e}^{(2)} \cdot \underline{e}_1 & \underline{e}^{(2)} \cdot \underline{e}_2 \end{bmatrix} \quad -(49)$$

proving that if:

$$\underline{e}^{a} = q^{a}_{\mu}\,\underline{e}^{\mu} \quad -(50)$$

then:

$$q^{a}_{\mu} = \underline{e}^{a}\cdot\underline{e}_{\mu} \quad -(51)$$

Q. E. D.

Extending this procedure to the linear momentum:

$$\begin{bmatrix}\underline{p}^{(1)}\\ \underline{p}^{(2)}\end{bmatrix} = \begin{bmatrix} q^{(1)}_{1} & q^{(1)}_{2}\\ q^{(2)}_{1} & q^{(2)}_{2}\end{bmatrix}\begin{bmatrix}\underline{p}^{1}\\ \underline{p}^{2}\end{bmatrix} \quad -(52)$$

so:

$$\begin{bmatrix}\underline{p}^{(1)}\\ \underline{p}^{(2)}\end{bmatrix}\cdot\begin{bmatrix}\underline{p}_{1} & \underline{p}_{2}\end{bmatrix} = \begin{bmatrix} q^{(1)}_{1} & q^{(1)}_{2}\\ q^{(2)}_{1} & q^{(2)}_{2}\end{bmatrix}\begin{bmatrix}\underline{p}^{1}\\ \underline{p}^{2}\end{bmatrix}\cdot\begin{bmatrix}\underline{p}_{1} & \underline{p}_{2}\end{bmatrix} \quad -(53)$$

It follows that:

$$\begin{bmatrix}\underline{p}^{(1)}\cdot\underline{p}_{1} & \underline{p}^{(1)}\cdot\underline{p}_{2}\\ \underline{p}^{(2)}\cdot\underline{p}_{1} & \underline{p}^{(2)}\cdot\underline{p}_{2}\end{bmatrix} = \begin{bmatrix} q^{(1)}_{1} & q^{(1)}_{2}\\ q^{(2)}_{1} & q^{(2)}_{2}\end{bmatrix}\begin{bmatrix}\underline{p}^{1}\cdot\underline{p}_{1} & \underline{p}^{1}\cdot\underline{p}_{2}\\ \underline{p}^{2}\cdot\underline{p}_{1} & \underline{p}^{2}\cdot\underline{p}_{2}\end{bmatrix} \quad -(54)$$

In the Cartesian basis of three dimensional space:

$$A = \begin{bmatrix}\underline{p}^{1}\cdot\underline{p}_{1} & \underline{p}^{1}\cdot\underline{p}_{2}\\ \underline{p}^{2}\cdot\underline{p}_{1} & \underline{p}^{2}\cdot\underline{p}_{2}\end{bmatrix} = \begin{bmatrix} p_{x}^{2} & 0\\ 0 & p_{y}^{2}\end{bmatrix} \quad -(55)$$

and the inverse matrix is:

$$A^{-1} = \frac{1}{p_X^2 p_Y^2}\begin{bmatrix} p_Y^2 & 0 \\ 0 & p_X^2 \end{bmatrix} \quad -(56)$$

Therefore the tetrad matrix is:

$$\begin{bmatrix} q^{(1)}_{\ 1} & q^{(1)}_{\ 2} \\ q^{(2)}_{\ 1} & q^{(2)}_{\ 2} \end{bmatrix} = \begin{bmatrix} \underline{p}^{(1)} \cdot \underline{p}_1 & \underline{p}^{(1)} \cdot \underline{p}_2 \\ \underline{p}^{(2)} \cdot \underline{p}_1 & \underline{p}^{(2)} \cdot \underline{p}_2 \end{bmatrix}\begin{bmatrix} 1/p_X^2 & 0 \\ 0 & 1/p_Y^2 \end{bmatrix} \quad -(57)$$

with individual components:

$$q^{(1)}_{\ 1} = \frac{1}{p_X^2}\underline{p}^{(1)} \cdot \underline{p}_1 = \frac{1}{\sqrt{2}}, \quad q^{(1)}_{\ 2} = \frac{1}{p_Y^2}\underline{p}^{(1)} \cdot \underline{p}_2 = -\frac{i}{\sqrt{2}},$$

$$q^{(2)}_{\ 1} = \frac{1}{p_X^2}\underline{p}^{(2)} \cdot \underline{p}_1 = \frac{1}{\sqrt{2}}, \quad q^{(2)}_{\ 2} = \frac{1}{p_Y^2}\underline{p}^{(2)} \cdot \underline{p}_2 = \frac{i}{\sqrt{2}}. \quad -(58)$$

Similarly:

$$q^{(3)}_{\ 3} = \frac{1}{p_Z^2}\underline{p}^{(3)} \cdot \underline{p}_3 = 1. \quad -(59)$$

and:

$$p^2 = p_X^2 + p_Y^2 + p_Z^2 = \underline{p}^{(3)} \cdot \underline{p}_3 + \sqrt{2}\left(\underline{p}^{(1)} \cdot \underline{p}_1 - i\,\underline{p}^{(2)} \cdot \underline{p}_2\right) \quad -(60)$$

which is Eq. (39) Q. E. D.

The quantization of these classical equations requires the following definitions of the Schroedinger postulate:

$$\hat{p}^{(0)}\psi = i\hbar\frac{\partial\psi}{\partial t} \quad -(61)$$

$$\hat{p}^{(1)}\psi = -\frac{i\hbar}{\sqrt{2}}\left(\frac{\partial\psi}{\partial X} - i\frac{\partial\psi}{\partial Y}\right), \quad -(62)$$

$$\hat{p}^{(2)}\psi = -\frac{i\hbar}{\sqrt{2}}\left(\frac{\partial\psi}{\partial X} + i\frac{\partial\psi}{\partial Y}\right), \quad -(63)$$

$$\hat{p}^{(3)}\psi = -i\hbar\frac{\partial\psi}{\partial Z}, \quad -(64)$$

$$\hat{p}_{(0)}\psi = i\hbar\frac{\partial\psi}{\partial t}, \quad -(65)$$

$$\hat{p}_{(1)}\psi = -\frac{i\hbar}{\sqrt{2}}\left(\frac{\partial\psi}{\partial X} - i\frac{\partial\psi}{\partial Y}\right) \quad -(66)$$

$$\hat{p}_{(2)}\psi = -\frac{i\hbar}{\sqrt{2}}\left(\frac{\partial\psi}{\partial X} + i\frac{\partial\psi}{\partial Y}\right) \quad -(67)$$

$$\hat{p}_{(3)}\psi = -i\hbar\frac{\partial\psi}{\partial Z} \quad -(68)$$

In order to transform the Hamilton Jacobi formalism (44) to a minimal prescription use:

$$\epsilon = E - V \quad -(69)$$

where V is the potential energy introduced by the frame transformations (28) and (29).

From Eqs. (44) and (69):

$$(E-V)^2 = E^2 + V^2 - 2EV = E^2 - c^2(p^2 - \pi^2). \quad -(70)$$

In the approximation:

$$E = \gamma mc^2 \to mc^2 \quad -(71)$$

Eq. (70) produces:

$$V^2 - 2mc^2V + c^2(p^2 - \pi^2) = 0 \quad -(72)$$

from which:

$$V = 2mc^2\left(1 \pm \left(1 - \frac{(p^2 - \pi^2)}{m^2c^2}\right)^{1/2}\right). \quad -(73)$$

In the limit:

$$p = \pi \quad -(74)$$

there is no potential energy, so the negative root is required in Eq. (73) and:

$$V = 2mc^2\left(1 - \left(1 - \frac{(p^2 - \pi^2)}{m^2c^2}\right)^{1/2}\right). \quad -(74)$$

In Eq. (73), use:

$$\text{Real}\left(p^2 - \pi^2\right) = \left(p_x^2 + p_y^2\right)\left(1 - \cos\phi\right) \quad -(75)$$

so Eq. (44) becomes:

$$E - V - mc^2 = \frac{c^2\pi^2}{E - V + mc^2}. \quad -(76)$$

In the approximation (71):

$$E - mc^2 = V + \frac{c^2\pi^2}{2mc^2 - V}. \quad -(77)$$

If it is assumed that:

$$V \ll 2mc^2 \quad -(78)$$

then

$$E - mc^2 = \frac{\pi^2}{2m} + V \quad -(79)$$

Finally, for:

$$\pi \sim p \quad -(80)$$

The Schroedinger limit is obtained by regarding the energy of the Schroedinger equation as $E - mc^2$, so:

$$E\psi = \left(-\frac{\hbar^2}{2m}\nabla^2 + V\right)\psi \quad -(81)$$

with:

$$V = 2mc^2\left(1 - \left(1 - \frac{(p_x^2 + p_y^2)(1 - \cos\phi)}{m^2c^2}\right)\right)^{1/2} \quad -(82)$$

In section 4 this equation is solved for the transmission coefficient of quantum tunnelling in LENR.

4. ILLUSTRATIONS OF THE TRANSMISSION COEFFICIENT OF LENR WITH POTENTIAL ENERGY FROM SPACETIME.

Section by Horst Eckardt and Douglas Lindstrom.

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4. ILLUSTRATIONS OF THE TRANSMISSION COEFFICENT OF LENR WITH POTENTIAL ENERGY FROM SPACETIME

To understand the carbon oxygen nucleus impact as discussed in UFT Paper 228- 230 as a possible experimental indicator of low energy nuclear reactions, the conditions in the carbon arc electric discharge were modelled using the equations of this paper to see the likelihood of quantum tunnelling at the energy levels available from an arc situation.

Equation (82) caN be simplified using the condition of equation (78) to

$$V = \frac{(p_x^2+p_y^2)}{\mu}\left(1-Cos(\varphi)\right) \tag{83}$$

where μ is the reduced mass of the projectile.

Given that the momentum density of an electromagnetic wave as

$$\frac{p}{volume} = \frac{W}{c^2}$$

where W is the instantaneous energy flux of an electromagnetic wave,

equation (83) becomes

$$V = \frac{1}{\mu}\left(\frac{W}{c^2}\ \ projectile\ volume\right)^2 \left(1-Cos(\varphi)\right)$$

so that if r_p is the radius of the projectile particle then

$$V = \frac{1}{\mu}\left(\frac{W}{c^2}\frac{4\,\mu\, r_p^3}{3}\right)^2 \left(1-Cos(\varphi)\right) \tag{84}$$

This value for the potential provided by an electromagnetic wave allows the transmission coefficient for an LENR event to be calculated as in previous papers UFT 228-230.

The data for the oxygen nucleus, the target, impacted with the carbon nucleus, the projectile, were available in the literature and reported earlier. For this calculation we take:

Potential well depth (MeV)	93.89	V_0
Nucleus base particle radius (m)	1.18 x 10^{15}	r_0
Nucleus radius (m)	$r_0\left(A_p^{1/3} + A_t^{1/3}\right)$	r_r
Diffuseness of potential well (m)	0.454 x10^{-15}	a_r
Target Atomic Mass	15.9994	A_t
Projectile Atomic Mass	12.011	A_p

Following the lead of UFT Paper 228 and 229, equation (84) is normalized to give

$$\theta = Exp\left(\frac{\sqrt{2\mu V_0}a_r}{\hbar}\int_a^b\left(\frac{-1}{1+Exp\left(\frac{\eta-1}{\eta_0}\right)} + V_c - \lambda - \frac{1}{\mu V_0}\left(\frac{W}{c^2}\frac{4\,\mu\,r_p^3}{3}\right)^2\left(1 - Cos(\varphi)\right)\right)^{1/2}\right)d\eta \qquad (85)$$

where

$$\eta = \frac{r}{r_r}$$

$$\eta_0 = \frac{a_r}{r_r}$$

$$\lambda = \frac{E}{V_0}$$

$$\chi = \frac{1}{\mu V_0}\left(\frac{W}{c^2}\frac{4\,\mu\,r_p^3}{3}\right)^2$$

$$r_p = r_0 A_p^{1/3}$$

$$V_c = \frac{z_p z_t e^2}{4\pi\epsilon_o V_0 r_r \eta} \qquad \eta \geq 1$$

$$V_c = \frac{z_p z_t e^2}{8\pi\epsilon_o V_0 r_r}(3-\eta^2) \qquad \eta < 1$$

Comparing the integral of equation (85) with that of the preceding papers, we see the added term

$$\frac{1}{\mu V_0}\left(\frac{W}{c^2}\frac{4\,\mu\, r_p^3}{3}\right)^2 \left(1 - Cos(\varphi)\right)$$

which serves to lower the Coulomb barrier.

A full calculation of the transmission coefficients is beyond the scope of this paper since it requires an assumption on projectile velocities and mass flow rates, data which is unknown at this time. However we do show a plot of the argument of the radical of equation (85) for some assumed values for the experimental variables, in Figure 1.

A point of interest is the dependence of the integration limits and the size of the argument o the Coulomb barrier between the two nuclei to be overcome. The transmission coefficient for such an arrangement is .61 for $\varphi = 0$ and 0.63 for $\varphi = \pi$, illustrating a potential reaction increase.

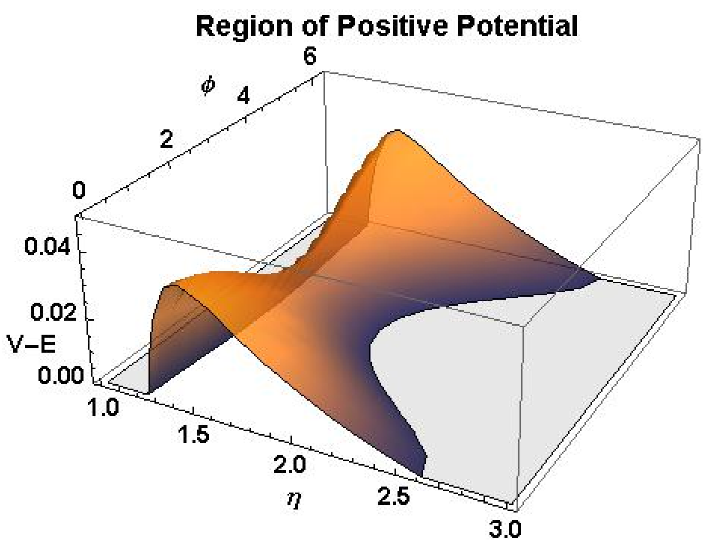

Figure 1 Plot of positive region of argument of radical in equation (85) with $\chi = .1, \lambda = .05$