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Luminiferous Æther[1]

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ABSTRACT: This article aims to demonstrate that the vacuum is not an empty space and, on the contrary, it is a space of high density energy. We will calculate the mechanical and electromagnetic properties of the vacuum and demonstrate that transverse waves, like electromagnetic, need a high density medium to propagate light with velocity $c \approx 3 * 10^8 m s^{-1}$. This is the substratum, medium or Luminiferous Æther where the electromagnetic waves travel in.

KEYWORDS: luminiferous æther, vacuum, light velocity, electromagnetic waves, mechanical waves, waves in solids, solid medium.

Contents

1 Symbology

In this text we will use the following symbols with its abbreviated units of measure:

N = Newton, kg = kilogram, m = meter, s = second, V = Volt, C = Coulomb, A = Ampère, Wb = Weber, rad = radian.

E = Electric field intensity [N C^{-1}] [V m^{-1}];
ε_0 = Electric permittivity of vacuum [C^2 N^{-1} m^{-2}] [C V^{-1} m^{-1}];
$\varepsilon = \varepsilon_r \varepsilon_0$ = Electric permittivity of the dielectric material [C^2 N^{-1} m^{-2}] [C V^{-1} m^{-1}];
H = Magnetic field intensity [N Wb^{-1}] [A m^{-1}];
B = Surface density of magnetic charge [Wb m^{-2}];
μ_0 = Magnetic permeability of vacuum [Wb^2 N^{-1} m^{-2}] [Wb A^{-1} m^{-1}];
$\mu = \mu_r \mu_0$ = Magnetic permeability of the material [Wb^2 N^{-1} m^{-2}] [Wb A^{-1} m^{-1}];

1 The word Æther is used here to distinguish it from the commonly used chemical fluid ether, and Luminiferous because this specific type of æther is the medium or substratum for the propagation of light.
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G = Gravitational field intensity [N kg^{-1}] [m s^{-2}];
V_G = Gravitational potential [N m kg^{-1}] [m^2 s^{-2}];
q_G = Gravitational charge [kg];
ρ_G = Volumetric density of gravitational charge [kg m^{-3}];
α_G = Linear density of gravitational charge [kg m^{-1}];
γ_0 = Gravitational permeability of vacuum [kg^2 N^{-1} m^{-2}] [kg s^2 m^{-3}];
k_G = Gravitostatic constant = $6.6739*10^{-11}$ [N m^2 kg^{-2}] [m^3 kg^{-1} s^{-2}];
I = Inertial field intensity [N s m^{-2}] [kg m^{-1} s^{-1}];
O = Surface density of inertial charge [s^{-1}];
q_I = Inertial charge [m^2 s^{-1}];
I_I = Inertial current [m^2 s^{-2}];
ι_0 = Inertial permeability of vacuum [$(m^2 s^{-1})^2$ N^{-1} m^{-2}] [m^2 N^{-1} s^{-2}] [m kg^{-1}];
F = Force [N] [kg m s^{-2}];
v = Velocity [m s^{-1}];
c = Speed of light in vacuum = $2.9979*10^8$ m s^{-1};
f = Frequency [Hz];
$\omega = 2\pi f$ = Angular frequency [rad s^{-1}];
r = Radial length (radius) [m];
l = Length [m];
S = Area [m^2].

2 Introduction

The vacuum of space is composed of a vast spectrum of radiations: Cosmic Microwave Radiation (CMR) whose microwave spectrum was mapped by COBE space satellite from NASA, sparse light particles like hydrogen and helium, cosmic rays with high energy particles, Cosmic Background Radiation (CBR) that are beyond our technical capacities and so on. Below these, like a substrate, there are what was called Luminiferous Æther, the carrier of light, the medium where radiations or electromagnetic waves travel in. The concept behind the Luminiferous Æther was that waves need a medium or a substratum to propagate.

In the chapter IV of the Einstein's Theory of Relativity book by Max Born[1] we read: "The fact that certain physical events propagate themselves through astronomic space led long ago to the hypothesis that space is not empty but filled with an extremely fine imponderable substance, the æther, which is the carrier or medium of these phenomena. So far as this conception of the æther is still used nowadays it is taken to mean nothing more than empty space associated with certain physical states or 'fields'".

This was an abstract conception that failed to explain the majority of the problems related with æther. The text continues and gives a rough outline about two theories on the propagation of light through space:

1. "The corpuscular theory asserts that luminescent bodies send out fine particles that move in accordance with the laws of mechanics and that produce the sensation of light when they strike the eye."
2. "The undulatory theory assumes the existence of a medium that permeates all transparent bodies and that can execute vibrations; this is the luminiferous æther. In this process of vibration the individual particles of this substance move only with a pendular-like motion about their positions of equilibrium. That which moves on as the light-wave is the state of motion of the particles and not the particles themselves."

In the chapter 1.1 of An Introduction to Relativity, by Jayant Narlikar[2], we read: "Although Newton had (wrongly) resisted the notion that light travels as a wave, during the nineteenth century the concept of light travelling as a wave had become experimentally established through such

phenomena as interference, diffraction and polarization. However, this understanding raised the next question: in what medium do these waves travel? For, conditioned by the mechanistic thinking of the Newtonian paradigm, physicists needed a medium whose disturbance would lead to the wave phenomenon. Water waves travel in water, sound waves propagate in a fluid, elastic waves move through an elastic substance... so light waves also need a medium called æther in which to travel."

By the beginning of the XIX century, Fresnel and Arago made a decisive experiment that drew the inference that light vibrations must be transverse. From the same text of Max Born[1]: "The vibrations of the æther particles do not occur in the direction of propagation, but perpendicularly to it, that is, in the plane of the wave. … After the transversality of light had been proved by numerous experiments, there arose in Fresnel's mind the vision of a future dynamical theory of light, which was to derive optical phenomena from the properties of the æther and the forces acting in it, in conformity with the method of mechanics. The æther was necessarily a kind of elastic solid, for it is only in such a substance that mechanical transverse waves can occur. So, Fresnel's results appeared to confirm the analogy of light waves with elastic waves."

With elastic waves on a one-dimensional medium, like a chord or string, a mechanical force perturbs this medium and produces a mechanical wave that propagates one-dimensionally, following only the chord/string direction. If there is not the chord/string, there would be no way for this mechanical wave to propagate. This is what occurs in the other directions where there are not medium, so a mechanical wave do not propagate without an adequate medium that transports the stress energy that deformed it. Because the medium has mechanical elasticity, it is possible to cause a stress on it and create the perturbation that is propagated on it.

The analogy of light waves with mechanical waves lead physicists to think that electric and magnetic fields produce a stress in the æther and there is a deformation in this medium proportional to the amplitude of the original fields. This perturbation is propagated with velocity c because the medium has elasticity. We do not create waves, but only perturbations in elastic mediums that determine the propagation velocity of this perturbations in wave forms. The wave is the medium propagating the perturbation thanks to its elasticity, that is its capacity to deform with a stress. A wave is only created in a medium that has capacity to suffer stress; without an adequate medium, there is no wave.

The consequence of this analogy is that the cause of the wave is not the fields associated with it, but the stress suffered by the medium. The energy that causes this stress must interact with the medium to produce a deformation that we call field, and it is this perturbation or deformation that is propagated thanks to the elasticity of the medium. What we call fields are the amplitude of the deformation energy being transported by the medium. Without medium, no fields and no waves.

And this leads us to question whether this medium has electromagnetic properties and transports electromagnetic waves, or the electromagnetism appears only when the æther wave interacts with matter. Ignoring this and other possibilities, it will be calculated some ætheric mechanical and electromagnetic characteristics using the gravitational permeability γ_0, inertial permeability ι_0, electric permittivity ε_0 and magnetic permeability μ_0 of the vacuum.

In previous articles[3] it was introduced a form of presentation for the gravitational and inertial equations that is similar to its electromagnetic counterparts. This new form of presentation for the gravitoinertial fields permits us to make analogies between electromagnetic and mechanical waves and deduce mechanical properties for the vacuum. In calculating these mechanical properties it was found that the old concept of a substrate, a medium or, more specifically, a luminiferous æther is logical and theoretically correct.

3 Please see Gravitational Charge, Inertial Field and Gravitoinertial Fields articles at the bibliography.

3 Mechanical Characteristics of Vacuum

The mechanical characteristics of vacuum may be confirmed by the analogy between the equation of motion of electromagnetic and mechanical waves. This analogy considers that the electromagnetic characteristics ε_0 and μ_0 of the medium (vacuum) determines the velocity of the electromagnetic waves and the mechanical characteristics γ_0 and ι_0 of the medium (vacuum) determines the speed of the mechanical waves, and both are the speed of light in vacuum, as we already have calculated in the Gravitoinertial Fields[3] article.

The propagation velocity of a mechanical one-dimensional traveling wave may be deduced studying the equation of motion for a vibrating string of finite length displaced on the x-coordinate, stretched horizontally and fastened at each end, and set into vibration. For small amplitudes of vibration on the y-coordinate, the tension T [N] constant and density of gravitational charge (mass) of the string per unit length α_G [N m^{-1}], the equation of motion is:[4]

$$\frac{\partial^2 y}{\partial x^2}-\frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}=0 \quad \text{with} \quad v=\sqrt{\frac{T}{\alpha_G}} \quad \text{or} \quad v^2=\frac{T}{\alpha_G}$$

This equation is the same as the propagation velocity of a one-dimensional electromagnetic wave, substituting the y-coordinate by the electric field E_y or magnetic field H_z, that are transverse to the x-direction of propagation. Here $v=\sqrt{T/\alpha_G}$ is the motion velocity of the mechanical wave on the string in the x-direction. This equation is analogous to the motion velocity of mechanical waves in solids, liquids and gases:

- For elastic solids: $v=\sqrt{\frac{E}{\rho_G}}$ or $v^2=\frac{E}{\rho_G}$
- For liquids and gases: $v=\sqrt{\frac{B}{\rho_G}}$ or $v^2=\frac{B}{\rho_G}$

For these equations, ρ_G [kg m^{-3}] is the volumetric density of gravitational charge (mass) of the medium. For solids, E [N m^{-2}] is the elastic or Yang modulus (elasticity or rigidity); for liquids, B [N m^{-2}] is the bulk modulus; for gases, B [N m^{-2}] is the adiabatic bulk modulus. These equations are for volumetric or three-dimensional mediums.

In the linear or one-dimensional string case, both the tension T (stretching or traction force) and the density of the string per unit length α_G are defined in the same area (the transverse section of the string), so both areas cancel in the velocity equation. Then, the same equation for propagation velocity for elastic solids could be used for the string.

Liquids and gases do not propagate transverse waves inside of it, only longitudinal ones; but on the surface that limits two mediums with different densities it is possible to propagate transverse waves, like the water waves produced between water and air. Transverse waves, like electromagnetic, need a solid medium to propagate inside of it, so we will use the analogy between mechanical waves in solids considering that the vacuum is like an elastic solid medium. Liquid media composed of particles that have angular momentum also propagate transverse waves, so we will make a rough approximation considering this possibility.

In the Inertial Field[5] article, we have defined the gravitational potential by $V_G=v^2=I_I$, so, the gravitational potential of the string/elastic solid is given by the propagation velocity squared, and this is the inertial current of the string/elastic solid. In each point of the string/elastic solid, the gravitational potential is constant and depends only on the mechanical characteristics of the string like tension T and linear density α_G, or the mechanical characteristics of the elastic solid like elastic modulus (Yang modulus) E and volumetric density of gravitational charge ρ_G.

In vacuum, considering that gravitation is a central force, the gravitational potential at a distance r from a gravitational charge q_G is given by:

$$V_G = G\,r = \frac{1}{4\pi\gamma_0}\frac{q_G}{r}$$

The distance r limits a spherical shell centered in q_G. The division by solid angle 4π is needed because the gravitational potential is calculated only in one point of the spherical shell, that has the same gravitational potential all over its surface. So, substituting the linear density of gravitational charge $\alpha_{G0} = q_G/4\pi\gamma_0 = 1/\iota_0$, as we have calculated in the Gravitoinertial Field[3] article, we have:

$$V_G = \frac{\alpha_{G0}}{\gamma_0} = \frac{1}{\iota_0\gamma_0} = c^2 = I_I$$

3.1 Mechanical Waves in a String

For a string, that is a one-dimensional medium, there is no need for a division by 4π. This way, for the string, $\alpha_G = q_G/r$ corresponds to the linear density of gravitational charge, and the inertial permeability ι of the string may be calculated by the inverse of this quantity:

$$\iota = \frac{1}{\alpha_G} = \frac{r}{q_G}[m\,kg^{-1}]$$

The gravitational potential of the string may be calculated by:

$$V_G = \frac{1}{\gamma}\frac{q_G}{r} = \frac{\alpha_G}{\gamma} \quad \text{, and} \quad V_G = v^2 = \frac{T}{\alpha_G} = \frac{\alpha_G}{\gamma}$$

The gravitational permeability of the string may be calculated by:

$$\gamma = \frac{\alpha_G^2}{T} = \frac{\alpha_G}{v^2}$$

And the tension T, that is a traction force that stretch the string, is equivalent to a gravitational force similar to the gravitational force between two equal gravitational charges. So, the string is a continuous distribution of punctual gravitational charges. Both equations are given here for comparison:

$$T = \frac{\alpha_G^2}{\gamma} = \frac{1}{\gamma}\frac{q_G^2}{r^2} \quad \text{and} \quad F = \frac{1}{4\pi\gamma_0}\frac{q_G^2}{r^2}$$

Substituting the linear density of gravitational charge $\alpha_G = 1/\iota$ in the gravitational potential equation obtained above, we have the gravitational potential of the chord/string defined in the same way as the vacuum:

$$V_G = \frac{\alpha_G}{\gamma} = \frac{1}{\gamma\iota} = v^2 = I_I$$

3.2 Mechanical Waves in Solids

For an elastic solid, that is a three-dimensional medium, we must deal with the volumetric density of gravitational charge ρ_G [kg m^{-3}], and the inertial permeability ι of the solid may not be calculated by the inverse of this quantity because its unit of measure is [m kg^{-1}]. Because the area is

the same for the numerator and denominator, we may note that the relation $v^2=E/\rho_G$ is the same as $v^2=T/\alpha_G$. So, we may calculate the tension T and the linear density of gravitational charge α_G of the elastic solid and evaluate its volumetric density of gravitational charge and elastic modulus E.

The gravitational potential of the elastic solid may be calculated considering that the linear density is $\alpha_G=q_G/4\pi\gamma=1/\iota$, as we have calculated in the Gravitoinertial Field[3] article:

$$V_G=\frac{1}{4\pi\gamma}\frac{q_G}{r}=\frac{\alpha_G}{\gamma} \quad \text{, and} \quad V_G=v^2=\frac{T}{\alpha_G}=\frac{\alpha_G}{\gamma}$$

The gravitational permeability of the solid may be calculated by:

$$\gamma=\frac{\alpha_G^2}{T}=\frac{\alpha_G}{v^2}$$

And the tension T, that is a traction force that stretch the solid, is equivalent to a gravitational force similar to the gravitational force between two equal gravitational charges. So, the solid is a continuous distribution of punctual gravitational charges. Substituting the linear density of gravitational charge $\alpha_G=1/\iota$ in the gravitational potential equation obtained above, we have:

$$V_G=v^2=\frac{1}{\gamma\iota}=I_I$$

And now we have to consider the Gravitational Poisson's equation $\rho_G=-\gamma\nabla^2V_G$ that we have exposed in the Gravitational Charge[6] article to deduce that the volumetric density is the laplacian of the linear density:

$$\rho_G=-\gamma\nabla^2V_G=-\gamma\nabla^2\left(\frac{q_G}{4\pi\gamma r}\right)=-\nabla^2\left(\frac{q_G}{4\pi r}\right)=-\nabla^2\alpha_G$$

Mathematically this makes sense. For a solid material, the relation between the linear density and volumetric density comes from:

$$\alpha_G=\frac{q_G}{4\pi r} \quad \text{and} \quad \rho_G=\frac{q_G}{4/3\pi r^3}=\frac{3q_G}{4\pi r^3}$$

Considering that both density equations are by unity of length (r = 1), we have $\rho_G=3\alpha_G$. We may calculate the elastic modulus E by the $v^2=E/\rho_G$ relation:

$$E=\rho_G v^2=3\alpha_G v^2=3T$$

3.3 Mechanical Waves in Vacuum

The gravitational potential equation for the string relates the propagation velocity of the mechanical wave with the gravitational permeability and inertial permeability of the string $\gamma\iota=1/v^2$ in similar way that the propagation speed of electromagnetic waves (speed of light) is related with the gravitational and inertial permeabilities of vacuum $\gamma_0\iota_0=1/c^2$.

This lead us to conclude that the vacuum is a mechanical medium too and the speed of light c is the velocity for mechanical waves (like the gravitational ones).

Considering that the linear density of gravitational charge (mass) is given by $\alpha_G = q_G/(4\pi r)$, the gravitational potential of the vacuum may be related with the linear density of gravitational charge (mass) of vacuum:

$$V_G = \frac{1}{4\pi\gamma_0}\frac{q_G}{r} = \frac{\alpha_{G0}}{\gamma_0}$$

We may relate the speed of light c with the equation of the propagation velocity of mechanical waves $c^2 = T_0/\alpha_{G0}$ like if the vacuum would be a mechanical medium whose propagation velocity for mechanical waves is c:

$$V_G = c^2 = \frac{1}{\gamma_0\iota_0} = \frac{\alpha_{G0}}{\gamma_0} = \frac{T_0}{\alpha_{G0}}$$

This is a gravitational potential $V_G = T_0/\alpha_{G0}$ produced by a linear density of gravitational charge stretched by a tension. The inertial permeability of vacuum and the linear density of gravitational charge was calculated in the Gravitoinertial Fields[3] article, and this vacuum tension (mechanical force) may be calculated using the last equation:

$$T_0 = \frac{\alpha_{G0}^2}{\gamma_{G0}} = \alpha_{G0}c^2 = \frac{c^2}{\iota_0} = \frac{1}{\iota_0\varepsilon_0\mu_0} = 9.6257*10^{42}\,N$$

The vacuum elastic modulus (mechanical pressure that determines the elasticity or rigidity) may be calculated using the relation between the linear density and volumetric density:

$$E_0 = 3T_0 = 3*9.6257*10^{42} = 2.8877*10^{43}\,N\,m^{-2}$$

This is the traction pressure that maintains the (volumetric density of gravitational charge of the) vacuum stretched and is the cause that defines the propagation velocity $c \approx 3*10^8\,m\,s^{-1}$ for electromagnetic transverse waves, like the velocity of mechanical transverse waves are determined by the elastic modulus in solids or the tension on the chord/string.

The volumetric density of gravitational charge ρ_G may be obtained using the value of the inertial permeability of vacuum or the linear density of gravitational charge calculated in the Gravitoinertial Fields[3] article.

$$\rho_{G0} = 3\alpha_{G0} = 3*1.0716*10^{26} = 3.2148*10^{26}\,kg\,m^{-3}$$

With this volumetric density of gravitational charge, the vacuum is a solid with a very high density, it is not an empty space. The electromagnetic waves, by its similarity with the waves in elastic solids or on chords/strings, are perturbations propagated in a medium, the substrate called luminiferous æther, where the light travels with speed c. This medium has mechanical properties determined by its gravitational permeability γ_0 and inertial permeability ι_0.

4 Electromagnetic Characteristics of Vacuum

In this article, it is not our intention to define what luminiferous æther is or what composes it, but only to calculate its properties. Perhaps someone may be induced to think that “luminifeours æther” means that this medium is luminous, but in this article it is not the case, it means that it is the medium where light waves travel in. It will be considered that this medium interacts with

electromagnetic perturbations through the electric permittivity ε_0 and magnetic permeability μ_0 of the vacuum. So, there are two types of medium that presents electromagnetic properties that may be considered:

1. Solid dielectric
   Because of its high energy density and elastic modulus, this substrate behaves like an electric insulating solid material that has dielectric properties.
2. Ocean of photons
   The energy associated with this elastic modulus may be linked to a fluid composed by photons associated with an extremely high frequency. This is not like a background radiation because radiation is composed by waves produced by the motion of these photons.

4.1 Solid Dielectric

Any dielectric material submitted to time-varying electric fields looses its electrical isolating property in proportion to the field frequency. Capacitors are made with dielectric materials between two electrically conductive plates. The electric capacitance of a capacitor is calculated by:

$$C_E = \varepsilon \frac{S}{l}$$

With:

C_E = Electric capacitance [C^2 N^{-1} m^{-1}] [C V^{-1}] [F];
S = Area of the electric conducting plates and dielectric material [m^2];
l = Distance of the plates and thickness of the dielectric material [m].

This equation is similar to the electric conductance S_E of an electric conductor, and this lead us to conclude that the capacitance C_E is like a conductance and the permittivity ε is a conductivity measure for time-varying electric fields. The conductance equation is:

$$S_E = \sigma_E \frac{S}{l}$$

With:

S_E = Electric conductance [Ω^{-1}];
σ_E = Electric conductivity [Ω^{-1} m^{-1}];
S = Area of the electric conducting material [m^2];
l = Length of the conducting material [m].

The electric resistance presented by a capacitor to the flowing of electrical current when it is submitted to a time-varying electric field is called capacitive reactance X_E. This equation is similar to the equation for the resistance of electric conductive materials. With these, we may obtain the electric reactive resistivity ρ_{XE} and the electric reactive conductivity σ_{XE}:

$$R_E = \rho_E \frac{l}{S} \qquad X_E = \frac{1}{2\pi f C_E} = \frac{1}{\omega C_E} = \frac{1}{\omega \varepsilon} \frac{l}{S} = \rho_{XE} \frac{l}{S} \quad \text{and} \quad \rho_{XE} = \frac{1}{\omega \varepsilon} \qquad \sigma_{XE} = \frac{1}{\rho_{XE}} = \omega \varepsilon$$

With:

R_E = Electric resistance [Ω];
ρ_E = Electric resistivity [Ω m];
X_E = Electric capacitive reactance [Ω];
ρ_{XE} = Electric reactive resistivity [Ω m];
σ_{XE} = Electric reactive conductivity [Ω^{-1} m^{-1}].

The same can be done for the magnetic reactive resistivity ρ_{XM} and get the magnetic reactive conductivity σ_{XM}:

$$C_M = \mu \frac{S}{l} \qquad X_M = \frac{1}{2\pi f C_M} = \frac{1}{\omega C_M} = \frac{1}{\omega \mu} \frac{l}{S} = \rho_{XM} \frac{l}{S} \quad \text{and} \quad \rho_{XM} = \frac{1}{\omega \mu} \qquad \sigma_{XM} = \frac{1}{\rho_{XM}} = \omega \mu$$

With:

C_M = Magnetic capacitance [$Wb^2\ N^{-1}\ m^{-1}$] [$Wb\ A^{-1}$] [H];
X_M = Magnetic capacitive reactance [Ω^{-1}];
ρ_{XM} = Magnetic reactive resistivity [$\Omega^{-1}\ m$];
σ_{XM} = Magnetic reactive conductivity [$\Omega\ m^{-1}$].

Now, we need to establish some parameters to get the real electric and magnetic reactances:

1. The electric and magnetic reactances calculated above use the angular frequency ω [rad s^{-1}] in the denominator, so we really have a reactance by radians unit of measure.
2. In a wave, the wavelength is the distance in which the magnetic or electric fields complete the perimeter of a circle, that is 2π radians.
3. So, to get the reactance of the vacuum for waves we have to divide the reactive resistivity by the wavelength and multiply by 2π radians.

Considering that $\omega = 2\pi f$, $\lambda = c/f$ and $c = 1/\sqrt{\varepsilon_0 \mu_0}$, we have the electric and magnetic reactances of the vacuum for electromagnetic waves:

$$X_E = \frac{2\pi}{\lambda} \rho_{XE} = \frac{\omega}{c} \rho_{XE} = \frac{1}{\varepsilon_0 c} = \sqrt{\frac{\mu_0}{\varepsilon_0}} = 376.7303\ Wb\, C^{-1} [\Omega]$$

$$X_M = \frac{2\pi}{\lambda} \rho_{XM} = \frac{\omega}{c} \rho_{XM} = \frac{1}{\mu_0 c} = \sqrt{\frac{\varepsilon_0}{\mu_0}} = \frac{1}{376.7303}\, C\, Wb^{-1} [\Omega^{-1}]$$

We see that:

$$X_E = \frac{1}{X_M} \Rightarrow \frac{2\pi}{\lambda} \rho_{XE} = \frac{\lambda}{2\pi} \frac{1}{\rho_{XM}} \Rightarrow \lambda = 2\pi \sqrt{\rho_{XE} \rho_{XE}} = 2\pi \sqrt{\frac{1}{\omega^2 \mu_0 \varepsilon_0}} = \frac{1}{f \sqrt{\mu_0 \varepsilon_0}} = \frac{c}{f}$$

We can confirm what was exposed above considering that $\vec{B} = \mu_0 \vec{H}$ and $\vec{c} = c\,\vec{k}$, with the unitary direction vector $\vec{k}$, in the relation:

$$\vec{E} = \vec{c} \times \vec{B} = \mu_0 c\, \vec{k} \times \vec{H} = \sqrt{\frac{\mu_0}{\varepsilon_0}} \vec{k} \times \vec{H} = X_E \vec{k} \times \vec{H} \Rightarrow X_E = \frac{E}{H}$$

This relation for the electric reactance is equivalent to the resistance for electric conductive materials $R = V/I$, so the electromagnetic wave propagation is equivalent to an electric current, and vice-versa.

Considering that $c = 1/\sqrt{\gamma_0 \iota_0}$, we have the gravitational and inertial reactances of the vacuum for gravitoinertial waves:

$$X_G = \sqrt{\frac{\iota_0}{\gamma_0}} = 2.79765 * 10^{-18}\, m^2 s^{-1} kg^{-1} \quad , \quad X_I = \sqrt{\frac{\gamma_0}{\iota_0}} = 3.55443 * 10^{18}\, kg\, m^{-2} s \quad \text{and} \quad X_G = \frac{1}{X_I}$$

With:

X_G = Gravitational capacitive reactance [$m^2\ s^{-1}\ kg^{-1}$];

X_I = Inertial capacitive reactance [kg m^{-2} s].

For gravitoinertial waves traveling in vacuum, we can have the same relation between electric and magnetic fields in electromagnetic waves. Considering that $\vec{O}=\iota_0\vec{I}$ and $\vec{c}=c\vec{k}$, with the unitary direction vector $\vec{k}$, in the relation:

$$\vec{G}=\vec{c}\times\vec{O}=\iota_0 c\,\vec{k}\times\vec{I}=\sqrt{\frac{\iota_0}{\gamma_0}}\vec{k}\times\vec{I}=X_G\vec{k}\times\vec{I} \;\Rightarrow\; X_G=\frac{G}{I}$$

4.2 Ocean of Photons

The medium that has so high volumetric density of gravitational charge may not have material but energy nature, or maybe even another unknown type of nature. In this section, it will be considered that this medium is composed by photons with or without linear momentum, so it behaves like an ocean of particles that must have angular momentum to propagate transverse waves.

The volumetric density of energy of this medium u_0 [J m^{-3}] is exactly its elastic modulus E_0 [N m^{-2}], because pressure in a fluid or solid is its measure of volumetric density of energy. So, with the equation developed we have:

$$V_G=c^2=\frac{T_0}{\alpha_{G0}}=\frac{E_0}{\rho_{G0}} \quad \text{and} \quad E_0=\rho_{G0}c^2=u_0$$

The elastic modulus E_0 [N m^{-2}] of the vacuum, that is like a pressure (force by area), is the volumetric density of energy u_0 [J m^{-3}] of the elastic solid. The equation $u_0=\rho_{G0}c^2$ for a known volume gives us the energy liberated when the matter of this volume is disintegrated $U=q_G c^2=m c^2$ so, this is the energy that maintains the matter aggregated. The equation of the propagation velocity of a wave in a solid medium is the same equation of mass-energy conversion:

$$c^2=\frac{E_0}{\rho_0}=\frac{u_0}{\rho_0}=\frac{U}{q_G}=\frac{U}{m}$$

To get an idea of what composes this medium, let's consider that the distribution of this vacuum energy can be compared to a black body radiation, so it obeys the Plank's distribution and the absolute temperature associated with it may be calculated by the relation:

$$\frac{c}{4}u(T)=\frac{\pi^2 k_B^4}{60\,c^2\hbar^3}T^4=\sigma T^4$$

With:

u(T) = Volumetric density of energy [J m^{-3}];
k_B = Boltzmann's constant = 1.381*10^{-23} J K^{-1};
h = Planck's constant = 6.6256*10^{-34} J s; $\hbar=h/2\pi$;
σ = Stefan-Boltzmann's constant = 5.6704*10^{-8} J m^{-2} s^{-1} T^{-4};
T = Temperature [K];

With $u_0=E_0=2.8877*10^{43}\,J\,m^{-3}[N\,m^{-2}]$, the absolute temperature T associated with this radiation is:

$$T=\left(\frac{u(T)c}{4\sigma}\right)^{1/4}=\left(\frac{2.8877*10^{43}*2.998*10^{8}}{4*5.6704*10^{-8}}\right)^{1/4}=4.420*10^{14}\,K$$

The frequency f_{max} of greater intensity is calculated by the Wien's Law:

$$f_{max} = 2.822 \frac{k_B T}{h} = 2.822 \frac{1.381 * 10^{-23} * 4.420 * 10^{14}}{6.6256 * 10^{-34}} = 2.600 * 10^{25} Hz$$

The wavelength λ_{max} of greater intensity of this frequency is:

$$\lambda_{max} = \frac{c}{f_{max}} = \frac{2.998 * 10^{8}}{2.600 * 10^{25}} = 1.153 * 10^{-17} m = 0.01153 Fermi$$

With these considerations, the volumetric density of energy of the vacuum has electromagnetic properties and its elastic modulus $E_0 = 2.8877 * 10^{43} N m^{-2}$ may be understood like a pressure caused by the presence of photons associated with a frequency of 2.600*10^{25} Hz. Here we have two interpretations:

1. These photons emit radiation and this elastic modulus is radiation pressure;
2. These photons are submitted to a, until now, not defined force that is the cause of this elastic modulus. An example of this phenomenon is the atmospheric pressure caused by the presence of gaseous molecules of the air submitted to the gravitational force of the planet.

Considering that the luminiferous æther is like an ocean of photons and that the electromagnetic waves are produced by the motion of these photons is coherent with mechanical waves. Sound waves are produced by the motion of the molecules that compose the air, water waves are produced by the motion of molecules of water, mechanical waves in solids are produced by the motion or vibration of the atoms that compose the solid. All these mediums must have elasticity to permit the motion of its constituents and propagate waves.

This is a rough approximation because this medium may not be radiation itself, but a fluid of another type of particles until now unknown that makes it behave like a superfluid.

5 Conclusion

With the old concept of the light wave analogy with a vibrating chord/string and properties of the capacitor with solid dielectric, the mechanical and electromagnetic properties of the vacuum may be mathematically deduced with the electromagnetic and gravitoinertial equations developed in previous articles. This raises again the concept of a medium or substratum where the waves travel in, the Æther Luminiferous, that has the properties of a solid to propagate transverse waves like electromagnetic.

The vacuum elastic modulus is $E_0 = 2.8877 * 10^{43} N m^{-2}$, and this is a mechanical pressure that determines the elasticity or rigidity of the medium, with associated energy density $u_0 = 2.8877 * 10^{43} J m^{-3}$. The vacuum volumetric density of gravitational charge is $\rho_{G0} = 3.2148 * 10^{26} kg m^{-3}$. These are extremely high values and lead us to think that matter is created like bubbles inside an ocean of very dense energy. In this way, matter is like attenuated Æther Luminiferous, a local where it is rarefied.

The electric and magnetic reactances of the vacuum to electromagnetic waves are $X_E = \sqrt{\mu_0 / \varepsilon_0} = 376.7303 \Omega$ and $X_M = \sqrt{\varepsilon_0 / \mu_0} = 1/376.7303 \Omega^{-1}$ confirmed by the relation $E = c B = \mu_0 c H = \sqrt{\mu_0 / \varepsilon_0} H = X_E H$, so $X_E = E / H$. This relation between electric and magnetic fields in an electromagnetic wave is analogous to the $R = V / I$ for electric circuits and lead us to conclude that the propagation of an electromagnetic wave behaves like an electric current, and vice-

versa. In this point of view, the electric current is consequence of electromagnetic wave propagation inside matter, and the low speed of carriers inside conductors is caused by photon collisions.

Considering that this vacuum energy obeys the Plank's distribution, the absolute temperature associated with this energy is $T = 4.420 * 10^{14} K$. The frequency of greater intensity calculated by the Wien's Law is $f_{max} = 2.600 * 10^{25} Hz$, whose associated wavelength is $\lambda_{max} = 1.153 * 10^{-17} m$. So the Æther Luminiferous may be associated to a fluid or an ocean of photons. In this way, as the mechanical waves, the electromagnetic waves travel in this medium as a consequence of the motion of these photons.

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