Dear Mr. Roger Shawyer.

I would like to congratulate you on your remarkable invention of the “EmDrive” engine, this principle of operation will be base of future technologies of transport and power engineering. This principle of operation is completely determined by classical electrodynamics, as it is, because the classical electrodynamics includes a physic and mathematical tool, the application of whish, gives the force that creates a movement that is not accompanied by the ejection of any substance or radiation.

It is the Darwin Lagrangian, which was derived in 1920 by Charles Darwin, grandson of the author of the theory of evolution [1]. It has an important role in the quantum-mechanical analysis of relativistic perturbations in atoms and given in such works of classical electrodynamics for theoretical physicists as “Field Theory” Landau and Lifshitz [2], Jackson [3], [4] and etc.

The same solution for two moving charged particles was obtained by Page and Adams in 1945 [5]. In accordance with it, a closed system containing two particles makes movement (including accelerated) along with its center of mass. But the scientific community has not reacted to this in any way.

The solution of the classical equation of motion, which follows from the Darwin's Lagrangian, is absent in any textbooks, and if it appeared there, one would have to cancel the Einstein’s postulates introduced into classical electrodynamics due to the collapse of the laws of conservation of momentum and energy, which the mainstream categorically does not accept. So ignore, although, in fact, everything is not so bad.

The Darwin’s Lagrangian for the system of particles differs from the Lagrange function adopted in mechanics that takes into account the magnetic interaction. It creates a force that can make the center of mass of a closed system perform accelerated movement. What is impossible in mechanics, it is legally and naturally existing in classical electrodynamics.

If the charges oscillate near fixed oppositely charged centers, they can be considered as elements of alternating current, and their resultant force will have a constant direction. It follows that if an alternating current flows along a conical surface (as in an EmDrive), the constant force will lie on the axis of the cone.

However, even the authors of “Field Theory” [2] always neglect the magnetic interaction of a system of moving particles and always assume the velocity of the center of mass to be constant in any inertial frame of reference, see, for example, Problem 2 to §75. If this approach is applied to the equation of motion with Darwin’s Lagrangian, see § 65, then the terms causing the magnetic interactions will disappear immediately, the electrodynamic equation of motion will undergo degradation into the mechanical one. But most theoretical physicists refer to "Field Theory" [2], as to the “Bible”, taking every word of the authors faithfully. What can they say about the emdrive apart from expressing their erroneous opinion that this device “contravenes all the known laws of physics”.

Page and Adams [5] surprisingly demonstrated the implementation of the momentum conservation law, despite the movement of the center of mass. They calculated the so-called "electromagnetic field momentum", defined through the product of the electric and magnetic fields created by the particles, and its time derivative was equal to the resultant force of a closed system of two particles. According to the analysis carried out by the author [6] (download according to the reference http://ivanov-georgij2010.narod.ru/o_book1.zip , unfortunately, this book in Russian only, for the present.)the resultant force is exactly equal to the magnetic force of Ampere, which acts on the current flowing through the physical vacuum of Maxwell's displacement current. In other words, this is a "reaction to a vacuum," thanks to which the momentum conservation law is fulfilled. In the same way it is performed in your “EmDrive”.

Thus, your “EmDrive” exists legally in classical electrodynamics. If we declare it outlawed, it means that out of the law will be the quintessence of classical electrodynamics - Darwin's Lagrangian and classical electrodynamics itself. In fact, only two generally known postulates of Einstein will be outlawed, which conflict not only with Darwin's Lagrangian, but

also with the much more obvious fact that the Lorentz transformation is the identical form of Galileo's transformations. In this connection, the Lorentz transformations are valid not only for the physical vacuum, but also for any acoustic wave-conducting medium. Such transformations, instead of the speed of light, contain the speed of sound, see [6], §2, §5.

Instead of the exhausted Special Theory of Relativity, the theory of the Lorentz ether, which is described in detail in his book "Theory of Electrons and Its Application to Phenomena of Light and Thermal Radiation", is ideally suited, see [7], [8]. It contains a position on the fixed ether, the form of matter, in an ideal approximation, having an infinitely large effective density and a position about relativity, according to which it is impossible to detect experimentally the reference frame in which the ether is at rest, assuming that all interactions in nature correspond to electromagnetic ones. If one discovers superlight interactions, then this frame of reference will become available for experimental observation.

Physical-mathematical details are given in the appendix below.

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APPENDIX

What follows from the Darwin Lagrangian

The universal law of conservation of momentum

The Lagrange function of a loop system two moving particles without magnetic interactions in mechanics has the form,

$$L = \frac{m_1 v_1^2}{2} + \frac{m_2 v_2^2}{2} - \frac{q_1 q_2}{R} \qquad (1)$$

where m_1, m_2 – the mass of particles, v_1, v_2 – their velocities, q_1, q_2 - electric charges, R - distance between charges.

Hence, the law of conservation of momentum **p** is,

$$\mathbf{p} = \mathbf{p}_1 + \mathbf{p}_2 = m_1\mathbf{v}_1 + m_2\mathbf{v}_2 = \text{const} \qquad (2)$$

And the resultant force of **F** will be equal to zero,

$$\mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2 = 0 \qquad (3)$$

The Darwin Lagrangian for a loop system of two moving charged particles, taking into account magnetic interaction, looks so,

$$L = T - \frac{q_1 q_2}{R} + \frac{q_1 q_2}{2c^2}\left[\frac{\mathbf{u}_1\mathbf{u}_2}{R} + \frac{(\mathbf{u}_1\mathbf{R})(\mathbf{u}_2\mathbf{R})}{R^3}\right] \qquad (3)$$

where $T = \frac{m_1 u_1^2}{2} + \frac{m_2 u_2^2}{2} + \frac{m_1 u_1^4}{8c^2} + \frac{m_2 u_2^4}{8c^2}$ – sum of the kinetic energies of the charges q_1, q_2 c with masses m_1, m_2 moving with velocities u_1, u_2 with the accuracy to terms of second order in u/c.

Функция Лагранжа имеет вид,

The Lagrange equation has the form,

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \mathbf{u}_1} + \frac{\partial L}{\partial \mathbf{u}_2}\right) = \frac{\partial L}{\partial \mathbf{R}_{12}} + \frac{\partial L}{\partial \mathbf{R}_{21}} \qquad (4)$$

where $\mathbf{R}_{12}$ and $\mathbf{R}_{21}$ – the radius vectors connecting q_1 charge about q_2 and a charge of q_2 to q_1.

The values,

$$\frac{\partial L}{\partial \mathbf{u}_1} = \mathbf{P}_1 = \mathbf{p}_1 + \frac{q_1}{c}\mathbf{A}_2, \quad \text{и} \quad \frac{\partial L}{\partial \mathbf{u}_2} = \mathbf{P}_2 = \mathbf{p}_2 + \frac{q_2}{c}\mathbf{A}_1 \qquad (5)$$

where $\mathbf{P}_1$, $\mathbf{P}_2$ are called "total momentum" or "generalized momentum" [10], $\mathbf{p}_1$, $\mathbf{p}_2$ – conventional mechanical impulses of each of particles, $\mathbf{A}_1$, $\mathbf{A}_2$ – vector potentials of Darwin.

$$\mathbf{A}_1 = \frac{q_1}{2c}\left[\frac{\mathbf{u}_1}{R} + \frac{(\mathbf{u}_1\mathbf{R})\mathbf{R}}{R^3}\right], \quad \mathbf{A}_2 = \frac{q_2}{2c}\left[\frac{\mathbf{u}_2}{R} + \frac{(\mathbf{u}_2\mathbf{R})\mathbf{R}}{R^3}\right] \qquad (6)$$

Since $\mathbf{R}_{12} = -\mathbf{R}_{21}$, a right member part of (4) vanishes. Hence, according to (4) and (5), we obtain,

$$\frac{d\mathbf{P}}{dt} = 0 \qquad (7)$$

where $\mathbf{P} = \mathbf{P}_1 + \mathbf{P}_2$ – the total momentum of the system.

Thus, in classical electrodynamics, in contrast to the mechanics, the total momentum is maintained, therefore, the usual mechanical momentum is not conserved, that is constantly ignored the most of physics. Such physicists say that the movement emdrive will not be coordinated with a law of conservation of momentum, without understanding that it will be coordinated with a conservation law of the TOTAL momentum, but not mechanical one. Some of them enter a hypothesis of the so-called "hidden momentum" which, however, contradicts existence usual magnetic Lorentz force of moving charges. Hence, the net (mechanical) force of F isolated systems of two particles will be equal to,

$$\mathbf{F} = \frac{d\mathbf{p}}{dt} = \frac{\mathbf{p}_1 + \mathbf{p}_2}{dt} = -\frac{d}{dt}\left(\frac{q_1}{c}\mathbf{A}_2 + \frac{q_2}{c}\mathbf{A}_1\right) = \mathbf{F}_m + \mathbf{F}_u + \mathbf{F}_w \qquad (8)$$

where $\mathbf{p} = \mathbf{p}_1 + \mathbf{p}_2$ – mechanical (conventional) momentum of system,

$$\mathbf{F}_{\boldsymbol{m}} = \frac{q_1 q_2}{c^2 R^3}\mathbf{R} \times (\mathbf{u}_1 \times \mathbf{u}_2) \qquad (9)$$

$$\mathbf{F}_u = \frac{q_1 q_2}{2c^2}\left[u_1^2 - u_2^2 - 3\frac{(\mathbf{u}_1\mathbf{R})^2}{R^2} + 3\frac{(\mathbf{u}_2\mathbf{R})^2}{R^2}\right]\frac{\mathbf{R}}{R^3} \qquad (10)$$

$$\mathbf{F}_w = -\frac{q_1 q_2}{2c^2}\left[\frac{\mathbf{w}_1 + \mathbf{w}_2}{R} + \frac{(\mathbf{w}_1 + \mathbf{w}_2)\cdot\mathbf{RR}}{R^3}\right] \qquad (11)$$

Force $\mathbf{F}_m$ is caused by magnetic interaction of particles, $\mathbf{F}_u$ and $\mathbf{F}_w$ their speeds and accelerations.

Detailed studies show that the Force $\mathbf{F}_w$ always compensated by so-called charge magnetodynamic force, which can be obtained either by using magnetodynamic force, known from the classical works of [1], [2], [3], either through a transition to a non-inertial reference systems, in which the accelerated particles are buried [4].

If the particles oscillate in the same phase about a fixed oppositely charged centers, the force F_u disappears [4]. Such particles can either be viewed as an oscillating electric dipole, or as elements alternating current (as in EmDrive). Their resultant force is due only to the magnetic interaction, the formula (9).If such particles lie on forming a cone, then net force will be directed on a cone axis. From couple of fluctuating particles by an integration it is easy to pass to alternating currents, then net force will be determined by Ampere's law. For example, it is equal in emdrive to the Ampere force acting on the conduction current flowing on a cone surface from the magnetic field formed by the displacement current of Maxwell flowing between end planes.

Now about the most interesting and most important.

On the basis of (6) and (8) the law of conservation of the total momentum **Φ** can be written in the form,

$$\mathbf{\Phi} = \frac{\mathrm{d}\mathbf{p}}{\mathrm{dt}} + \frac{\mathrm{d}}{\mathrm{dt}}\left\{\frac{q_1 q_2}{2c^2}\left[\left(\frac{\mathbf{u}_1}{\mathrm{R}} + \frac{(\mathbf{u}_1\mathbf{R})\mathbf{R}}{\mathrm{R}^3}\right) + \left(\frac{\mathbf{u}_2}{\mathrm{R}} + \frac{(\mathbf{u}_2\mathbf{R})\mathbf{R}}{\mathrm{R}^3}\right)\right]\right\} = 0 \qquad (12)$$

In 1945 Page and Adams [5] showed that expression in curly brackets is nothing else as the **G**-value known under the name "electromagnetic field momentum",

$$\mathbf{G} = \frac{1}{4\pi \mathrm{c}}\int (\mathbf{E}_1 \times \mathbf{H}_2 + \mathbf{E}_2 \times \mathbf{H}_1)\,\mathrm{dV} = \frac{q_1 q_2}{2c^2}\left[\left(\frac{\mathbf{u}_1}{\mathrm{R}} + \frac{(\mathbf{u}_1\mathbf{R})\mathbf{R}}{\mathrm{R}^3}\right) + \left(\frac{\mathbf{u}_2}{\mathrm{R}} + \frac{(\mathbf{u}_2\mathbf{R})\mathbf{R}}{\mathrm{R}^3}\right)\right] \qquad (13)$$

where $\mathbf{E}_1$, $\mathbf{E}_2$ and $\mathbf{H}_1$, $\mathbf{H}_2$ – the electric and magnetic fields created by charges of q_1, q_2. The integral is taken over all infinite space.

Change of the magnetic field due to the accelerated motion of particles, creates the force $\mathbf{F}_w$ (11) which, as stated above, compensated by charge magnetodynamic force. Thus, the magnetic field does not affect the value of G, that is why it is not a pulse. Hence, in classical electrodynamics, there is no "momentum of the electromagnetic field", and there is the so-called "impulse potential" G [4].

In this regard expression for force (12) can be presented as follows,

$$\mathbf{\Phi} = \frac{\mathrm{d}\mathbf{p}}{\mathrm{dt}} + \left(\frac{\mathrm{d}\mathbf{G}}{\mathrm{dt}}\right)_{\mathrm{H}} = 0 \qquad (14)$$

where the subscript "H" means that the differentiation is performed at constant magnetic field produced by moving charges or, in other words, at constant acceleration of these charges.

Whereas, (13), (14), we obtain,

$$\left(\frac{\mathrm{d}\mathbf{G}}{\mathrm{dt}}\right)_{\mathrm{H}} = \frac{1}{\mathrm{c}}\int (\mathbf{j}_{s1} \times \mathbf{H}_2 + \mathbf{j}_{s2} \times \mathbf{H}_1)\,\mathrm{dV} = \mathbf{F}_{\mathrm{E}} \qquad (15)$$

where $\mathbf{j}_{s1}$, $\mathbf{j}_{s2}$ – the displacement currents created by moving charges of q_1, q_2; $\mathbf{F}_E$ – the Ampere force acting on the Maxwell displacement currents flowing in a perfect vacuum from the magnetic fields created by charges.

Now it is possible to write down **the main law of conservation of momentum** in a classical electrodynamics,

$$\frac{\mathrm{d}}{\mathrm{dt}}(\mathbf{p} + \mathbf{G}) = 0, \quad \mathbf{p} + \mathbf{G} = \mathrm{const} \qquad (16)$$

As d**p**/dt is the resultant mechanical force of a loop system $\mathbf{F}_m$,

$$\mathbf{F}_m = -\mathbf{F}_E. \qquad (17)$$

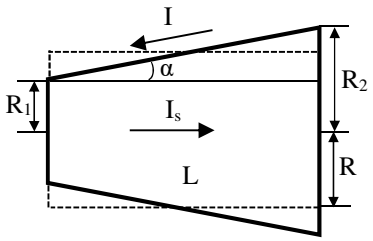
Thus, nonzero mechanical force, selfcontained, on the modern concepts, real system is balanced to the Ampere force acting on the displacement current of Maxwell flowing through a vacuum.

It is the present universal law of the nature demanding recognition of existence of such form of matter other than substance and the field which creates a possibility of driving of similar emdrive of the device, providing realization of laws of conservation of momentum and energy, specifically speaking, demanding recognition of the existence which is ideally satisfying to pressing needs of a classical electrodynamics, ether by Lorentz explicitly described in the book "Theory of Electrons" [6], [7].

Working principle and application prospects of EmDrive in the light of the universal law of conservation of momentum

Rate the force of the thrust EmDrive and the maximum values that are possible in the future.

At small angles α, see the drawing, between forming a cone and its axis, pressure upon a conic surface created by Ampere force will differ a little from pressure upon a cylindrical surface, designated in the drawing by dashed lines, what gives the chance of approximate assessment of the thrust force of emdrive. The displacement current I_s, flowing in the cone, equal to the current at the side surface of the conduction current I; we assume that the height of the cone L twice its average radius R; sin α = 0.1. Then the thrust EmDrive F will be equal to the ampere force multiplied by sin α.



$$F \cong \frac{\mu_0 L I_s^2}{2\pi R} \sin\alpha = \frac{\mu_0 I_s^2}{\pi} \sin\alpha \qquad (18)$$

where μ_0 – a permeability of vacuum.

The displacement (bias) current will be equal, $Is = 2\pi^2 R^2 \varepsilon_0 \nu E$ where ε_0 – a permittivity of vacuum; ν – a critical frequency of the cylindrical volume resonator [8], [9], E is the electric field strength. With respect to our parameters $\nu = 5{,}7*10^8$ Hz. The corresponding critical wavelength λ can be estimated as λ = c/ν = 0,53 m. From here we will get,

$$F \cong 0{,}9L^2 \frac{\varepsilon_0 E^2}{2} = 0{,}9L^2 w \qquad (19)$$

where w – density of energy of all electric field in emdrive.

Take into account that

$$w = \frac{W}{\pi R^2 L}$$

where W is the energy stored inside emdrive,

and that the quality of EmDrive equal to $Q=2\pi \nu W/N$, where ν is the resonant frequency, N is the heat power emitted by the walls of EmDrive.

Get out of here,

$$F \cong 0.24 \frac{NQ}{c} \qquad (20)$$

Taking N = 1 kW and Q = 1000, obtain $F = 0.8*10^{-3}$ N that in order of magnitude, consistent with the known media figures is – $1{,}2 *10^{-3}$N/kW.

According to a formula (19), force of draft is defined by a square of the characteristic size L^2 and a square of an electric intensity E^2. For emdrive a length of 1 m. when the maximum achievable field strength in a vacuum is 10^8 V/m (Volt/meter) the thrust force is approximately equal $4*10^4$ N (4 tons). At Q = 1000 the 40 GW power would be necessary, that is impossible. Thus, "superconducting emdrives" are necessary.

There is a much more efficient way to create large thrust forces. The volume of emdrive is approximately equal to L^3, so according to (19), the volume density of the force f can be represented in the form,

$$f = 0.45\varepsilon_0 \frac{E^2}{L} \qquad (21)$$

We see that the smaller L is, the more f. If the volume equal to one cubic meter, stuff made by the method of micro and nano technologies by cells of small dimensions, when $L = 10^{-4}$ m, $E = 10^8$ V/m, get the traction force of $4*10^8$ N or 40 kT (thousands of tons) or 40 kg/cm^3. Thus, there are solutions to all of life's energy and transport problems.

Let's note that estimating calculations were carried out for critical (lowest) frequency and a critical (lengthiest) wavelength. With larger frequencies (smaller lengths of waves) calculations would become much more difficult and the resulting force could another will turn out in size and the direction.

Hidden in classical electrodynamics the universal laws of conservation of energy and momentum provide new opportunities in various fields of human activities. The details are available in [4], which can be downloaded according to the reference

http://ivanov-georgij2010.narod.ru/o_book1.zip

Unfortunately, this book in Russian only, for the present.

*The list of references for the **appendix***

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