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THE UNIVERSAL FORMULA FOR ENERGY. THE FUNDAMENTAL CONSTANT OF ENERGY

Abstract: *A universal energy law is proposed in the form of a formula that includes the energy constant and dimensionless parameters. This way of representing the energy formula is a generalized equation for mechanical, electric, magnetic, gravitational and thermal energy. From one generalized energy equation directly follows: kinetic energy formula $E=mV^2/2$, quantum energy formula $E=h\nu$, Einstein formula $E=mc^2$, thermal energy formula $E=3k_BT/2$, Joule-Lenz law, gravitational energy formula, electrical energy, magnetic energy, charged capacitor energy, inductance coil energy, rotational kinetic energy. The universal energy formula includes a single energy constant (E_0 = 8.18710577... x 10^{-14} J). The energy constant is numerically equal to the resting energy of the electron. Despite the electromagnetic status of this constant, it is a constant not only in the laws of electromagnetic energy, but also in the laws of mechanical energy, gravitational energy, and thermal energy. The dimensionless quantities are represented by the ratio of the used characteristics to the constants of these characteristics. The Universal formula of energy will facilitate the study and understanding of the laws of mechanics, gravitation and electromagnetism in the educational process.*

Keywords*: Universal formula of energy, Joule-Lenz law, Einstein formula, fundamental constant of energy, physical laws, physical constants, relationship of fundamental constants.*

1. Introduction

In recent years, there has been a growing interest in the analytical calculation of fundamental physical constants [1 - 13]. This is largely due to the problem of obtaining a more accurate value of the Newtonian constant of gravitation G by the method of measurement.

In [14, 15, 16] the reason for the similarity of the formulas of Coulomb's law and Newton's law of gravity was investigated:

$$F_K = k\frac{q_1 \bullet q_2}{r^2} \;;\; F_N = G\frac{m_1 \bullet m_2}{r^2}.$$

Similar similarity have the formulas of kinetic energy, magnetic energy, electrical energy:

$$E = \frac{m \bullet V^2}{2} \;;\; E = \frac{L \bullet I^2}{2} \;;\; E = \frac{C \bullet U^2}{2},$$

where: m - mass; V - speed; L - inductance; I - electric current; C - electric capacitance; U - voltage.

Energy laws and force laws, as a rule, are represented by mathematical formulas, which include a dimensional constant and dimensional parameters. In [14] it is shown that the fundamental laws of force in mechanics and in electromagnetism can be represented by two kinds of equivalent formulas.

The first type is the mathematical formulas, which include the dimensional constant and dimensional parameters. The constant in physical laws is necessary for the coordination of dimensions. Dimensional parameters in formulas of force laws are characteristics of interacting objects. Newton's law of gravitation, Coulomb's law, Ampere's law, Newton's second law, Lorentz force, etc. are usually represented in such familiar form.

The second type of representation of laws of nature are mathematical formulas, in which there is a dimensional constant and dimensionless parameters [14]. The dimensionality of the constant corresponds to the sought value. The parameters in the formulas of laws are dimensionless quantities. The dimensionless quantities are represented by the ratio of the used physical characteristics to the constants of these characteristics. As a result, Coulomb's law, Newton's law of gravity, Ampere's law, Newton's second law, Lorentz's force, etc. can be represented by two equivalent formulas. For example, Coulomb's law can be represented by such two equivalent formulas (Fig. 1) [14, 15, 16]:

$$F_K = k\frac{q_1 \bullet q_2}{r^2} = 8.9875\ldots \bullet 10^9 \bullet \frac{q_1 \bullet q_2}{r^2}$$

$$F_K = F_0 \bullet \left\{\frac{k_{q1} \bullet k_{q2}}{k_r}\right\} = 29.0535101\ \ldots \bullet \left\{\frac{k_{q1} \bullet k_{q2}}{k_r}\right\}$$

Fig.1. Two equivalent formulas of Coulomb's law. F_K - *Coulomb interaction force, k- interaction constant (* $k = 1/4\pi\varepsilon_0$ *= 8.9875...x10*^{9}*),* ε_0 *- electric constant,* q_1*,* q_2 *- charges of interacting bodies, r - distance,* k_{q1}*,* k_{q2}*,* k_r *- dimensionless quantities (*$k_{q1}=q_1/e$*,* $k_{q2} = q_2/e$*,* $k_r=r^2/r_e^2$*) .*

Newton's law of gravity can be represented by these two equivalent formulas (Fig. 2):

$$F_N = G\frac{m_1 \bullet m_2}{r^2} = 6.6743\ldots \bullet 10^{-11} \bullet \frac{m_1 \bullet m_2}{r^2}$$

$$F_N = F_0 \bullet \left\{\frac{k_{m1} \bullet k_{m2}}{D_0 \bullet k_r}\right\} = 29.0535101 \bullet \left\{\frac{k_{m1} \bullet k_{m2}}{D_0 \bullet k_r}\right\}$$

Fig.2. Two equivalent formulas of Newton's law of gravitation. F_N *- Newtonian interaction force, G - Newtonian constant of gravitation,* m_1*,* m_2*,- masses of interacting bodies, r - distance,* k_{m1}*,* k_{m2}*,* k_r*,* D_0 *- dimensionless quantities (*$k_{m1}=m_1/m_e$*,* $k_{m2} = m_2/m_e$*,* $k_r=r^2/r_e^2$*),* D_0 *- large Dirac number (*D_0 *= 4.16561...x 10*^{42} *).*

The second form of representation of force interaction laws turned out to be common to all force laws. As a result, a universal force formula was obtained [14, 15, 16]. Besides the universal force formula, the second form of representation of physical laws allowed us to obtain analytical formulas for calculating some constants, including the Newtonian constant of gravitation G. By analogy with the universal force formula [14], the generalized energy law is proposed in this paper.

2. Generalized equation of energy for mechanics, gravitation, thermodynamics and electromagnetism

The generalized equation of energy by its structure contains an energy constant E_0 and dimensionless quantities $k_1 ... k_4$ (Fig. 3). The following dimensional characteristics are reduced to dimensionless quantities in the energy equation: mass, charge, distance, speed, acceleration, time, frequency, temperature, electric current, voltage, electrical resistance, magnetic induction, electrical capacitance, inductance.

The design of the generalized energy equation is shown in Fig. 3:

Energy E = (Energy constant E_0) • (Dimensionless values $k_1 ... k_4$)

Fig. 3. Construction of the generalized energy equation using the energy constant and dimensionless quantities.

It is shown below that the energy constant E_0 is easily obtained by equivalent transformations of known energy laws. The reduction of dimensional characteristics to dimensionless quantities is not difficult with the use of fundamental physical constants. Combination of particular equations of energy allows to receive the general formula of energy for laws of mechanics, electromagnetism, thermodynamics.

3. Generalized formula for kinetic energy

Let's represent the equation of kinetic energy as the product of the energy constant E_0 by dimensionless quantities k_m, k_V. Let's represent dimensionless quantity km as the ratio of mass to the mass constant, the mass of the electron. The dimensionless quantity k_V will be represented as the ratio of the squared velocity value V to the squared velocity constant. The stepwise transition from the known equation of kinetic energy to its generalized formula is as follows:

$$E = \frac{mV^2}{2} = E_0 \bullet \left\{ \frac{m}{m_e} \bullet \frac{V^2}{c^2} \bullet \frac{1}{2} \right\} = m_e c^2 \bullet \left\{ k_m \bullet k_V \bullet \frac{1}{2} \right\} = 8.1871057 \ldots \bullet 10^{-14} \bullet \left\{ k_m \bullet k_V \bullet \frac{1}{2} \right\} J \quad (1)$$

where: m_e - electron mass, c - speed of light in vacuum.

Thus, the kinetic energy formula can be represented by the following generalized equation:

$$E = \frac{mV^2}{2} = m_e c^2 \bullet \left\{ k_m \bullet k_V \bullet \frac{1}{2} \right\} J \qquad (2)$$

In the generalized form the equation of kinetic energy is represented by the constant E_0 = 8.18710577... x 10^{-14} J and by dimensionless factors $k_m = m/m_e$, 1/2, $k_V = V^2/c^2$. The energy constant E_0 in the generalized kinetic energy formula is represented by formula:

$$E_0 = m_e c^2 = 8.1871057... \bullet 10^{-14}\ J \qquad (3)$$

Despite the electromagnetic status of the constant E_0, it is a constant in the law of kinetic energy. The generalized kinetic energy formula is the full equivalent of the original kinetic energy formula.

4. Generalized formula for electrostatic energy

Equation for electrostatic energy will be presented as a product of energy constant E_0 by dimensionless quantities k_{q1}, k_{q2}, k_r. Let us use dimensionless quantities to represent electric charges and distance. Let's represent dimensionless quantities k_{q1}, k_{q2} as the ratio of interacting electric charges to the fundamental physical constant - the electron charge ($k_{q1}=q_1/e$, $k_{q2} = q_2/e$). Let's represent the dimensionless quantity related to distance as the ratio of distance to the fundamental constant - the classical radius of the electron ($k_r=r/r_e$). The stepwise transition from the known electrostatic energy equation to its generalized formula is as follows:

$$E = k\frac{q_1 \bullet q_2}{r} = E_0 \bullet \left\{ \frac{\frac{q_1}{e} \bullet \frac{q_2}{e}}{\frac{r}{r_e}} \right\} = k\frac{e^2}{r_e} \bullet \left\{ \frac{k_{q1} \bullet k_{q2}}{k_r} \right\} = \frac{\hbar \bullet c \bullet \alpha}{r_e} \bullet \left\{ \frac{k_{q1} \bullet k_{q2}}{k_r} \right\} = \qquad (4)$$
$$= 8.1871057\ ... \bullet 10^{-14} \bullet \left\{ \frac{k_{q1} \bullet k_{q2}}{k_r} \right\} J$$

where: e - electron charge; $\hbar$ *- Planck's constant;* $k = 1/4\pi\varepsilon_0$*,* r_e *- classical electron radius; c - speed of light in vacuum;* α *- finite-structure constant.*

In generalized form the equation for electrostatic energy is represented by the constant E_0 = 8.1871057... x 10^{-14} J and dimensionless quantities $k_{q1} = q_1/e$, $k_{q2} = q_2/e$, $k_r = r/r_e$. The energy constant E_0 in the generalized law is represented by formulas:

$$E_0 = \frac{k \bullet e^2}{r_e} = \frac{\hbar \bullet c \bullet \alpha}{r_e} = 8.1871057... \bullet 10^{-14}\ J \qquad (5)$$

The generalized electrostatic energy formula is the complete equivalent of the original electrostatic energy formula.

5. Generalized formula for gravitational energy

The equation for gravitational energy will be presented as a product of energy constant E_0 by dimensionless quantities k_{m1}, k_{m2}, k_r. Let's represent electric charges and distance as dimensionless quantities. Let's represent dimensionless quantities k_{m1}, k_{m2}, connected with masses as ratio of masses to fundamental constant - mass of electron ($k_{m1} = m_1/m_e$, $k_{m2} = m_2/m_e$). The dimensionless quantity k_r related to distance will be represented as the ratio of distance to the fundamental constant - the classical radius of the electron ($k_r = r/r_e$). It is known that the electromagnetic interaction force and gravitational interaction force between two electrons are related to each other via dimensionless number (D_0 = 4.16561...x 10^{42}), which is referred to the family of large Dirac numbers [17, 18].

The stepwise transition from the gravitational energy equation to its generalized formula has the form:

$$E = G\frac{m_1 \bullet m_2}{r} = E_0 \bullet \left\{ \frac{\frac{m_1}{m_e} \bullet \frac{m_2}{m_e}}{\frac{r}{r_e}} \right\} = \frac{G \bullet m_e^2}{r_e} \bullet \left\{ \frac{k_{m1} \bullet k_{m2}}{k_r} \right\} = \frac{G \bullet m_e^2 \bullet D_0}{r} \bullet \left\{ \frac{k_{m1} \bullet k_{m2}}{D_0 \bullet k_r} \right\} = 8.1871057... \bullet 10^{-14} \bullet \left\{ \frac{k_{m1} \bullet k_{m2}}{D_0 \bullet k_r} \right\} \quad (6)$$

where: m_e - electron mass; G - Newtonian constant of gravitation; r_e - classical electron radius.

In the generalized form the gravitational energy equation is represented by the constant E_0 = 8.1871057... x 10^{-14} J and by dimensionless factors $1/D_0$ = 1/4,16561... x 10^{42} , $k_{m1} = m_1/m_e$, $k_{m2} = m_2/m_e$, $1/k_r = r_e/r$. The constant E_0 = 8.1871057... x 10^{-14} J in the generalized equation is represented by formula:

$$E_0 = G\frac{m_e^2 \bullet D_0}{r_e} = 8.1871057... \bullet 10^{-14} \; J \qquad (7)$$

The generalized gravitational energy formula is the full equivalent of the original gravitational energy formula.

6. Generalized formula for the energy of the quantum.

The generalized formula for the energy of the quantum will be presented as the product of the energy constant E_0 by the dimensionless quantity k_v. The dimensionless quantity kv will be presented as a ratio of frequency to the frequency constant v_0 ($v_0 = c/r_e$). The step-by-step transition from the quantum energy equation to its generalized formula is as follows:

$$E = h\nu = E_0 \bullet \left\{ \frac{\nu}{\nu_0} \bullet 2\pi \right\} = \hbar \bullet \alpha \bullet v_0 \bullet \{k_v \bullet 2\pi\} = 8.1871057... \bullet 10^{-14} \bullet \{k_v \bullet 2\pi\} \, J \quad (8)$$

where: v_0 is the frequency constant ($v_0 = c/r_e$ = 1.063870853...10^{23} s-1), $\hbar$ - Planck constant; α - fine-structure constant.

The generalized formula for quantum energy is represented by the constant E_0 = 8.1871057... x 10^{-14} J and dimensionless quantities k_v and 2π . The energy constant E_0 in the generalized formula is represented as:

$$E_0 = \hbar \bullet \alpha \bullet v_0 = 8.1871057... \bullet 10^{-14} \; J \qquad (9)$$

The generalized formula for the energy of the quantum is the full equivalent of the original formula.

7. Generalized formula of heat energy

Generalized formula of thermal energy is presented as a product of energy constant E_0 by dimensionless quantity k_T. Let's represent the dimensionless value k_T as the ratio of temperature to the temperature constant T_0 ($T_0 = 5.9298965...10^8$ K). The step-by-step transition from the thermal energy equation to its generalized formula is as follows:

$$E = \frac{3}{2}k_B T = E_0 \bullet \left\{ \frac{T}{T_0} \bullet \frac{3}{2} \right\} = k_B T_0 \bullet \left\{ k_T \bullet \frac{3}{2} \right\} = 8.1871057\ldots \bullet 10^{-14} \bullet \left\{ k_T \bullet \frac{3}{2} \right\} J \quad (10)$$

where: T_0 is the temperature constant ($T_0 = 5.9298965...10^8$ K), k_B is the Boltzmann constant.

The generalized formula for thermal energy is represented by the constant $E_0 = 8.1871057... \times 10^{-14}$ J and the dimensionless value k_T. The energy constant E_0 in the generalized formula is represented as:

$$E_0 = k_B T_0 = 8.1871057... \bullet 10^{-14}\ J \qquad (11)$$

The generalized heat energy formula is the full equivalent of the original formula.

8. Generalized formula for electrical energy

Generalized formula of electrical energy E=UIt is presented as product of energy constant E_0 by dimensionless quantities k_U, k_I, k_t. Let's represent dimensionless quantities k_U, k_I, k_t as the ratio of voltage to voltage constant U_0 ($U_0 = 5.109989...10^5$ V) current to current constant I_0 ($I_0 = 1.704509...10^4$ A) time to time constant t_0 ($t_0 = 0.939963715...10^{-23}$ s). The stepwise transition from the electrical energy equation to its generalized formula is as follows:

$$E = UIt = E_0 \bullet \left\{ \frac{U}{U_0} \bullet \frac{I}{I_0} \bullet \frac{t}{t_0} \right\} = U_0 \bullet I_0 \bullet t_0 \bullet \{k_U \bullet k_I \bullet k_t\} = 8.1871057\ldots \bullet 10^{-14} \bullet \{k_U \bullet k_I \bullet k_t\}\ J \quad (12)$$

where: U_0 is the voltage constant, I_0 is the current constant, t_0 is the time constant.

The generalized formula for electrical energy is represented by the constant $E_0 = 8.1871057... \times 10^{-14}$ J and the dimensionless quantities k_U, k_I, k_t. The energy constant E_0 in the generalized formula is represented as:

$$E_0 = U_0 \bullet I_0 \bullet t_0 = 8.1871057... \bullet 10^{-14}\ J \qquad (13)$$

The generalized heat energy formula is the full equivalent of the original formula.

9. Generalized formula of Joule-Lenz law

The generalized formula of Joule-Lenz law $E=I^2Rt$ is presented as product of energy constant E_0 by dimensionless quantities k_R, k_I, k_t. Let's represent dimensionless quantities k_R, k_I, k_t as ratio of resistance to resistance constant R_0 ($R_0 = 29.9792458\ \Omega$) current to current constant I_0 ($I_0 = 1.704509...10^4$ A) time to time constant t_0 ($t_0 = 0.939963715...10^{-23}$ s). The stepwise transition from the electrical energy equation to its generalized formula is as follows:

$$E = I^2Rt = E_0 \bullet \left\{ \frac{I^2}{I_0^2} \bullet \frac{R}{R_0} \bullet \frac{t}{t_0} \right\} = I_0^2 \bullet R_0 \bullet t_0 \bullet \{k_I \bullet k_R \bullet k_t\} = 8.1871057\ldots \bullet 10^{-14} \bullet \{k_I \bullet k_R \bullet k_t\}\ J \quad (14)$$

where: R_0 is the resistance constant, I_0 is the current constant, t_0 is the time constant.

The resistance constant can be represented by the following equivalent formulas:

$$R_0 = \frac{Z_0}{4\pi} = \frac{R_K \bullet \alpha}{4\pi} = \frac{1}{4\pi\varepsilon_0 c} \qquad (15)$$

where: Z_0 - characteristic impedance of vacuum, R_K - von Klitzing constant, α - fine-structure constant.

Generalized formula of Joule-Lenz law is represented by constant E_0 = 8.1871057... x 10^{-14} J and dimensionless quantities k_I, k_R, k_t. The energy constant E_0 in the generalized formula is represented as:

$$E_0 = I_0^2 \bullet R_0 \bullet t_0 = \frac{I_0^2 \bullet Z_0 \bullet t_0}{4\pi} = \frac{I_0^2 \bullet R_K \bullet \alpha \bullet t_0}{4\pi} = 8.1871057... \bullet 10^{-14}\ J \qquad (16)$$

Generalized formula of Joule-Lenz law is the full equivalent of the original formula.

10. Generalized formula for energy of a charged capacitor

Generalized formula for energy of charged capacitor is presented as a product of energy constant E_0 by dimensionless quantities k_C, k_U, 1/2. Let us represent dimensionless quantities k_C, k_U as ratio of capacitance to capacitance constant C_0 (C_0 = 3.135381...10^{-25} F), voltage square to voltage square constant U_0 (U_0 = 5.109989...10^5 V). The stepwise transition from the energy equation of a charged capacitor to its generalized formula is as follows:

$$E = \frac{CU^2}{2} = E_0 \bullet \left\{ \frac{C}{C_0} \bullet \frac{U^2}{U_0^2} \bullet \frac{1}{2} \right\} = C_0 \bullet U_0^2 \bullet \{k_C \bullet k_U \bullet 1/2\} = 8.1871057... \bullet 10^{-14} \bullet \{k_C \bullet k_U \bullet 1/2\} J \quad (17)$$

where: U_0 is the voltage constant, C_0 is the capacitance constant.

The stepwise transition from the energy equation of a charged capacitor represented by a charge to its generalized formula has the form

$$E = \frac{q^2}{2C} = E_0 \bullet \left\{ \frac{C_0}{C} \bullet \frac{q^2}{e^2} \bullet \frac{1}{2} \right\} = C_0^{-1} \bullet e^2 \bullet \{k_C \bullet k_q \bullet 1/2\} = 8.1871057... \bullet 10^{-14} \bullet \{k_C \bullet k_q \bullet 1/2\} J \quad (18)$$

where: e is the electron charge, C_0 is the capacitance constant.

The generalized formula for the energy of a charged capacitor is represented by the constant E_0 = 8.1871057... x 10^{-14} J and the dimensionless quantities k_C, k_U, k_q, 1/2. The energy constant E_0 in the generalized formula is represented as:

$$E_0 = C_0 \bullet U_0^2 = \frac{e^2}{C_0} = 8.1871057... \bullet 10^{-14}\ J \qquad (19)$$

The generalized formula for energy of a charged capacitor is the complete equivalent of the original formula.

11. The generalized formula for the magnetic energy of an inductor coil

We present the generalized formula for energy of inductor coil as a product of energy constant E_0 by dimensionless quantities k_L, k_I, 1/2. Let us represent dimensionless quantities k_L, k_I as a ratio of inductance to inductance constant L_0 (L_0 = 2.81794...10^{-22} H), current to current constant I_0 (I_0 = 1.7045090...10^4 A). The stepwise transition from the energy equation of the inductance coil to its generalized formula is as follows:

$$E = \frac{L \bullet I^2}{2} = E_0 \bullet \left\{ \frac{L}{L_0} \bullet \frac{I^2}{I_0^2} \bullet \frac{1}{2} \right\} = L_0 \bullet I_0^2 \bullet \{k_L \bullet k_I \bullet 1/2\} = 8.1871057\ldots \bullet 10^{-14} \bullet \{k_L \bullet k_I \bullet 1/2\}\, J \quad (20)$$

where: L_0 is the inductance constant, I_0 is the current constant.

The generalized formula for the energy of the inductance coil is represented by the constant E_0 = 8.1871057... x 10^{-14} J and the dimensionless quantities k_L, k_I, 1/2. The energy constant E_0 in the generalized formula is represented as:

$$E_0 = L_0 \bullet I_0^2 = 8.1871057\ldots \bullet 10^{-14}\ J \quad (21)$$

The generalized energy formula for an inductor coil is the complete equivalent of the original formula.

12. Generalized formula for kinetic energy of rotational motion.

Generalized formula of kinetic energy of rotational motion is presented as product of energy constant E0 by dimensionless quantities k_m, k_r, k_v. We will represent the dimensionless quantity k_m as the ratio of the body mass to the fundamental constant m_e - to the electron mass. We will represent the dimensionless quantity k_r as the ratio of the square of the radius to the square of the classical radius of the electron. The dimensionless quantity k_v will be represented as the ratio of frequency to the frequency constant ($v_0 = c/r_e$ = 1.0638708...10^{23} s-1). The stepwise transition from the equation of kinetic energy of rotational motion to its generalized formula has the form:

$$E = mr^2v^2 = E_0 \bullet \left\{ \frac{m}{m_e} \bullet \frac{r^2}{r_e^2} \bullet \frac{v^2}{v_0^2} \right\} = m_e \bullet r_e^2 \bullet v_0^2 \bullet \{k_m \bullet k_r \bullet k_v\} = 8.1871057\ldots \bullet 10^{-14} \{k_m \bullet k_r \bullet k_v\}\, J \quad (22)$$

where: m_e - electron mass, r_e - classical electron radius , v_0 - frequency constant ($v_0 = 1/t_0 = c/r_e$).

The generalized formula for kinetic energy of rotational motion is represented by the constant E_0 = 8.1871057... x 10^{-14} J and dimensionless quantities k_m, k_r, k_v. The energy constant E_0 in the generalized formula is represented as:

$$E_0 = m_e \bullet r_e^2 \bullet v_o^2 = 8.1871057\ldots \bullet 10^{-14}\ J \quad (23)$$

Generalized formula of kinetic energy of rotational motion is the full equivalent of the original formula.

13. Universal formula of energy

Using the universal constant of energy E_0 the generalized formulas of energy laws will be presented by a single formula (Fig. 4):

$$E = 8.1871057...10^{-14} \bullet \{k_1 \bullet k_2 \bullet k_3 \bullet k_4\}$$

$$E = m_e c^2 (k_1 \bullet k_2 \bullet k_3 \bullet k_4)$$

Fig. 4. Universal formula of energy

This is the Universal formula of energy for all the energy laws discussed above. In its structure this formula is represented by the product of the fundamental constant of energy E_0 = 8.1871057 ... x 10^{-14} J by the dimensionless quantities (Fig. 4). The dimensionless quantities k_1 - k_4 are presented as ratios of physical characteristics of the interacting bodies to their physical constants.

From the Universal formula of energy directly follows the formula for kinetic energy $E=mV^2/2$ (where $k_1=m_1/m_e$, $k_2 = V^2/c^2$, $k_3=1/2$, $k_4=1$). Followed by the quantum energy formula $E=h\nu$, at $k_1=\nu/\nu_0$, $k_2 = 2\pi$, $k_3=1$, $k_4=1$. Followed Einstein formula $E=mc^2$, at $k_1=m_1/m_e$, $k_2 = 1$, $k_3=1$, $k_4=1$. Followed formula $E= 3k_BT/2$, with $k_1=T/T_0$, $k_2 = 3/2$, $k_3=1$, $k_4=1$. The Joule-Lenz law $E = I^2Rt$ follows, with $k_1=I^2/I_0^2$, $k_2 = R/R_0$, $k_3=t/t_0$, $k_4=1$. Followed formulas of gravitational energy, electric energy, magnetic energy, energy of a charged capacitor, energy of an inductance coil, kinetic energy of rotational motion (Fig. 5).

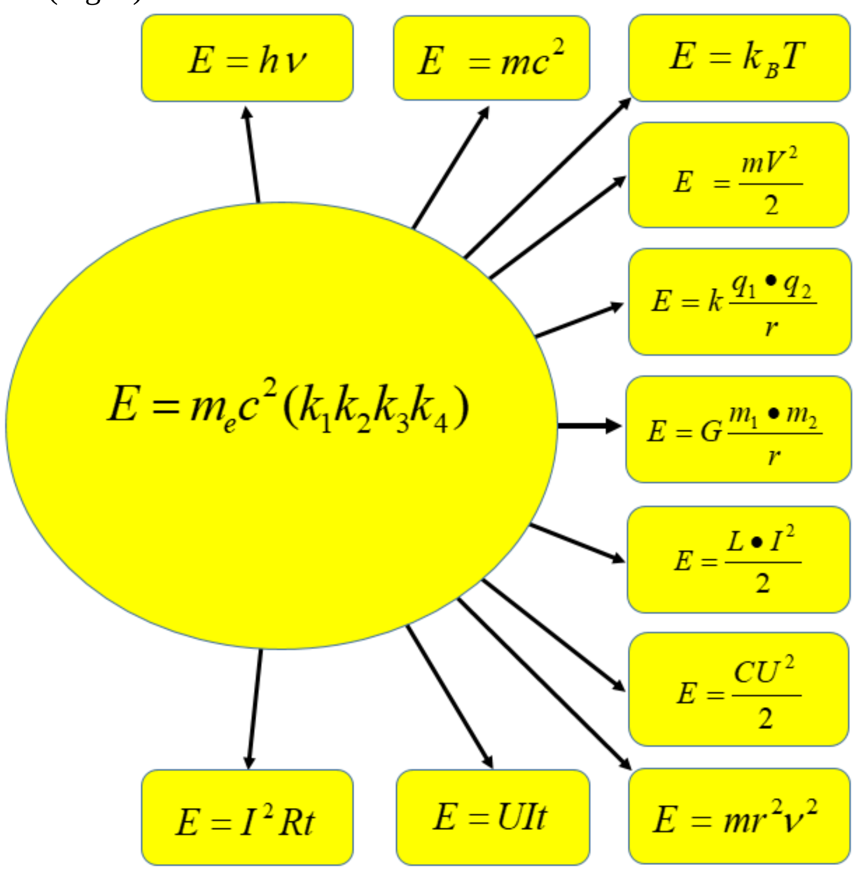

Fig. 5. From the Universal formula of energy follow the laws of energy of mechanics, gravitation, electromagnetism, thermodynamics.

14. Fundamental constant of energy

Generalized equations for all abovementioned laws of energy include the constant E_0 (Fig. 6):

$$\mathbf{E_0 = 8.1871057\ldots \times 10^{-14}\ J}$$

Fig. 6. Fundamental constant of energy.

We will call the constant E_0 = 8.1871057... x 10^{-14} J: "*Fundamental constant of energy*". This constant is the electron constant. Its value is the resting energy of the electron. Despite the electromagnetic status of this constant, it is a constant not only for the laws of electromagnetic energy, but also for the laws of mechanics and thermodynamics.

The electron constants (m_e, e, r_e) and the speed of light (c) are used to obtain dimensionless quantities [19]. The values of other constants used in the universal energy formula are given in the table (Fig. 7).

Name of the constant	**Value**	**Formula**
Time constant	$t_0 = 0.939963715\ldots 10^{-23}$ s	$t_0 = \frac{r_e}{c}$
Frequency constant	$\nu_0 = 1{,}063870853\ldots 10^{23}\ s^{-1}$	$\nu_0 = \frac{c}{r_e}$
Acceleration constant	$a_0 = 3.18940458\ldots 10^{31}$ m s^{-2}	$a_0 = \frac{r_e}{t_0^2}$
Temperature constant	$T_0 = 5.9298965\ldots 10^{8}$ K	$T_0 = m_e \bullet r_e^2 / k_B \bullet t_0^2$
Capacitance constant	$C_0 = 3.13538144\ldots 10^{-25}$ F	$C_0 = 4\pi\varepsilon_0 r_e$
Inductance constant	$L_0 = 2.81794032\ldots 10^{-22}$ H	$L_0 = \mu_0 \bullet r_e / 4\pi$
Current constant	$I_0 = 1.70450902\ldots 10^{4}$ A	$I_0 = e \bullet c / r_e$
Voltage constant	$U_0 = 5.10998949\ldots 10^{5}$ V	$U_0 = e / 4\pi\varepsilon_0 r_e$
Resistance constant	$R_0 = 29.9792458\ \Omega$	$R_0 = \sqrt{\frac{L_0}{C_0}} = \frac{Z_0}{4\pi} = \frac{R_K \bullet \alpha}{4\pi}$
Magnetic induction constant	$B_0 = 6{,}04877615\ldots 10^{11}$ T	$B_0 = \mu_0 \bullet e \bullet c / 4\pi\ r_e^2$

Fig. 7. Constants of physical characcteristics for obtaining dimensionless values.

15. Equivalent formulas to calculate the constant of energy E0

At least dozens of equivalent formulas can be offered to calculate the constant of E_0. Below, for example, there are 20 equivalent formulas for calculating the constant E_0 (Fig. 8).

$$E_0 = \left[\begin{matrix} \dfrac{\hbar \bullet c \bullet \alpha}{r_e} & G\dfrac{m_e^2 \bullet D_0}{r_e} & m_e \bullet c^2 & \dfrac{\hbar \bullet c}{l_{pl}^2 \bullet D_0} & \dfrac{I^2 \bullet t_0}{4\pi\varepsilon_0 c} \\ \dfrac{e^2}{4\pi\varepsilon_0 \bullet r_e} & \dfrac{E_h}{\alpha^2} & G\dfrac{m_{pl}^2 \bullet \alpha}{r_e} & \dfrac{I_0^2 \bullet R_K \bullet \alpha \bullet t_0}{4\pi} & L_0 \bullet I_0^2 \\ \dfrac{\hbar \bullet \alpha}{t_0} & \dfrac{2\mu_B \bullet m_e \bullet c \bullet \alpha}{e \bullet r_e} & \dfrac{\mu_0 \bullet I_0^2 \bullet r_e}{4\pi} & \dfrac{I_0^2 \bullet Z_0 \bullet t_0}{4\pi} & k_B T_0 \\ m_e \bullet r_e^2 \bullet v_o^2 & I_0^2 \bullet R_0 \bullet t_0 & \hbar \bullet \alpha \bullet \nu_0 & U_0 \bullet I_0 \bullet t_0 & C_0 \bullet U_0^2 \end{matrix} \right] = \mathbf{8.1871057\ldots J}$$

Fig. 8. Equivalent formulas for calculating the Fundamental constant of energy E_0 using the fundamental physical constants. *e - electron charge; $\hbar$ - Planck constant; G - Newtonian constant of gravitation , r_e - classical electron radius; c - speed of light in vacuum; α - fine-structure constant; t_0 - time constant ($t_0 = r_e/c$); π number, m_e - electron mass, Do - Dirac large number, μ_B - Bohr magneton, E_h - Hartree energy, l_{pl} - Planck length, m_{pl} - Planck mass. μ_0 - vacuum magnetic permeability, I_0 - current constant, U_0 - voltage constant, R_0 - resistance constant, C_0 - capacitance constant, L_0 - inductance constant, T_0 - temperature constant. R_K is the von Klitzing constant.*

It is difficult to give preference to any formula for calculating the constant of energy E_0. All formulas are equivalent. I am more inclined to $E_0 = \hbar\alpha\nu_0$ and $E_0 = m_e c^2$. At the same time, both formula $E_0 = \hbar\alpha\nu_0$ and formula $E_0 = m_e c^2$ can be derived from other energy constants. For example, the formula $E_0 = m_e c^2$ follows directly from the energy constant of a charged capacitor:

$$E_0 = C_0 \bullet U_0^2 = \frac{e^2}{C_0} = \frac{e^2}{4\pi\varepsilon_0 r_e} = \frac{(c\sqrt{4\pi\varepsilon_0 \bullet m_e r_e})^2}{4\pi\varepsilon_0 r_e} = m_e c^2 \quad (24)$$

The stepwise transition from $E_0 = C_0 \bullet U_0^2$ to $E_0 = m_e c^2$ uses the well-known ratio: $\alpha = e^2 / 4\pi\varepsilon_0 c\hbar$. From this formula it follows:

$$e = \sqrt{4\pi\varepsilon_0 \bullet c\hbar_u} = \sqrt{4\pi\varepsilon_0 \bullet c \bullet m_e r_e^2 / t_0} = c\sqrt{4\pi\varepsilon_0 \bullet m_e r_e} \quad (25)$$

The formula $E_0 = \hbar\alpha\nu_0$ too, is easily obtained from the energy constants given in the table (Fig. 7). For example, from the magnetic energy constant:

$$E_0 = L_0 \bullet I_0^2 = \frac{L_0 \bullet e^2}{t_0^2} = \frac{\mu_0 r_e}{4\pi} \bullet \frac{(c\sqrt{4\pi\varepsilon_0 \bullet m_e r_e})^2}{t_0^2} = \frac{\mu_0\varepsilon_0 m_e r_e^2 c^2}{t_0^2} = \frac{\mu_0\varepsilon_0 \hbar\alpha c^2}{t_0} = \frac{\hbar\alpha}{t_0} = \hbar\alpha\nu_0 \quad (26)$$

In turn, the formula $E_0 = \hbar \alpha \nu_0$ has a reduction to the formula $E_0 = m_e c^2$:

$$E_0 = \hbar \alpha \nu_0 = \frac{e^2 \bullet \nu_0}{4\pi\varepsilon_0 c} = \frac{c^2 4\pi\varepsilon_0 m_e r_e \bullet \nu_0}{4\pi\varepsilon_0 c} = m_e c^2 \quad (27)$$

The abundance of equivalent formulas for calculating the fundamental constant of energy E0 indicates a large number of dependent constants among the fundamental physical constants.

16. The Fundamental constant of energy E_0 reveals the mutual dependence of fundamental physical constants

A set of equivalent formulas for calculating the Fundamental constant of energy demonstrates the deep interrelation of the fundamental physical constants (Fig. 8).This exposes the problem of fundamental physical constants. This interrelation of constants indicates an excessive number of dependent constants among the fundamental physical constants. This means that there is a real chance to reduce all constants to an extremely small number of independent constants. The search for a primary independent constant basis among a large family of fundamental physical constants becomes an acute need. Only independent constants can be rightfully considered "*the most fundamental among all fundamental ones*". Signs of the primary status of constants (their fundamentality and independence) are their belonging to fundamental physical objects and simple dimensionality. The constants of the electron claim such a status. The main feature of secondary constants is their complex (composite) dimensionality and their origin from primary constants.

17. Conclusions

1. Energy laws, as a rule, are represented by mathematical formulas, which include a dimensional constant and dimensional parameters. Here energy laws are represented by mathematical formulas, which include the energy constant and dimensionless parameters.

2. The second form of energy laws representation allowed to obtain the universal formula of energy for mechanics, gravitation, thermodynamics and electromagnetism:

$$E = 8.1871057...10^{-14} \bullet (k_1 \bullet ... \bullet k_4) = \hbar \alpha \nu_0 \bullet (k_1 \bullet ... \bullet k_4) = m_e c^2 \bullet (k_1 \bullet ... \bullet k_4)$$

3. from universal formula of energy directly follow kinetic energy formula $E=mV^2/2$, quantum energy formula E=hν, Einstein formula $E=mc^2$, thermal energy formula $E= 3k_BT/2$, Joule-Lenz law, formulas of gravitational energy, electric energy, magnetic energy, energy of charged capacitor, energy of inductance coil, kinetic energy of rotational motion.

4 The universal energy formulaa includes the electromagnetic energy constant (E_0 = 8.18710577... x 10^{-14} J). Despite the electromagnetic nature of this constant, it is a constant not only in the laws of electromagnetic energy, but also in the laws of mechanical energy, gravitational energy, and thermal energy.

5. The possibility of calculating the constant of energy E_0 in many ways is shown. This is the evidence of a large number of dependent constants among fundamental physical constants. There is a

real chance to reduce them all to an extremely small number of independent constants. It is possible to form a minimal primary basis for all fundamental physical constants from independent constants.

6. Universal formula of energy will facilitate studying and understanding the laws of mechanics, gravitation and electromagnetism in the educational process.

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