Original Research Article

Basic Laws of EM Theory

Abstract: Instead of *electricity*, as the basic substance of EM theory, respective *static potential*, as some energetic fluid – manifest by the medium structure strain, is taken as the starting quantity. All the remaining EM quantities are defined in succession, by the standard *differential* equations, with *algebraic* relations and *central* laws derived from them, as their formal consequences. Not only that majority of the former results are thus confirmed, but some of them are finally completed, rationally interpreted and mutually related. On the other hand, a few formal concepts appear as inadequate or excessive at least.

Keywords: *EM theory, differential equations, algebraic relations, central laws*

1. INTRODUCTION

EM forces are ascribed to electricity, as the bipolar substance. Elementary forces between two charges, in the functions of their mutual position, simultaneous motion and acceleration of one of them, are to be expressed by respective central laws. On one hand, these laws should be generalized into *algebraic relations* between moving bodies – as the carriers and objects, and – on the other, into respective differential relations in the medium. Not only that such two-directional development is very complicated, but it is only incompletely carried out [1]. Apart from adequate explanation of the known intuitive and empirical relations, remaining problems are mainly resolved in [2], with consistent fulfillment of the inherited gaps. Instead, successive introduction and relation of EM quantities here starts from the static potential, as some energetic fluid, at least in the conditional sense.

The bipolar static potential, as the electric disturbance around carrying charges, is projected from 4D space, along temporal axis [3]. Tending to the absolute medium homogeneity and neutrality [4], two equipolar particles mutually repel, and opposite ones attract each other. In the form of some energetic fluid, the potential is followed by the medium polarization, which variations form respective displacement currents. Being elastically restricted by the medium, these currents demand the continual motion of the carriers in 3D or 4D spaces. Such two parallel currents interact by transverse kinetic forces, known as the magnetic field. Against their variation, the medium reacts by dynamic forces, as induction or inertia, proportional to the medium density. The speed of propagation is determined by the product of the *elasticity* and *density* of the vacuum medium, in the form: $c^2 = 1/\varepsilon\mu$.

After successive introduction of the standard *differential* equations, relating EM fields and/or potentials on the three kinematical states, their carriers and objects, as the moving bodies, are here related *algebraically*. In the final instance, *central laws* determine the elementary interactions of two punctual charges, in the functions of their respective kinematical relations: mutual position, simultaneous motion and acceleration of at least one of them. The two latter basic sets are elaborated and completed. All their equations are finally formulated, and the ranges of their application precisely determined. With mutual relation of the known, being so far independent empirical facts and/or particular physical relations, a few nearly forgotten problematic experimental results are convincingly explained. The completed, consistent and convincing EM theory is thus obtained and briefly presented.

2. STATIC RELATIONS

Static potential is related with energy density. Its own gradient is maintained by the opposite medium polarization. Owing to the inverse force function, the medium is denser around the smaller (positive), and sparser around greater (negative) particles. Tending to the medium homogeneity, equipolar particles mutually repel, and opposite ones attract each other. One medium strain, as the elementary potential, provides the energy for all other such strains, as the *objects*. The potential determines the *static field* (1a), as the medium stress. Depending on the medium elasticity and static field, some electric displacement $(\mathbf{D} = \varepsilon \mathbf{E})$ is thus formed, and its divergence just represents the carrying *charge* (1b):

$$\mathbf{E} = -\nabla \Phi \,, \qquad\qquad Q = \nabla\cdot\mathbf{D} \,. \tag{1}$$

Each new member of the three static quantities is the formal feature of the preceding one. The static field is the mere gradient of respective potential. The field line beginnings are considered as positive, and terminals – as negative charges. Thus introduced, the static quantities are the bases for following definition of kinetic ones.

3. KINETIC RELATIONS

3.1 Convective Phase

The former phase of the kinetic interactions concerns the production of kinetic, by motion of static quantities. The medium non-resistance enables the smooth displacement currents, at motion of the static quantities through 3D space or along temporal axis. In parallel with the current field defined (2a), the common motion of static potential, as the medium strain, forms the *kinetic* potential (2b), as respective linear momentum density:

$$\mathbf{J} = Q\mathbf{V} \,, \qquad\qquad \mathbf{A} = \varepsilon\mu\Phi\mathbf{V} \,. \tag{2}$$

The product of the elasticity, density and strain disturbance, gives the density disturbance ($\varepsilon\mu\Phi$), and its motion represents the kinetic potential ($\mathbf{A}$). The moving charges and their potentials form the two collinear quantities: electric current and kinetic potential. At motion of the negative static quantities, the two kinetic are opposite.

Starting from (2), as the two definitions of kinetic, – by motion of static quantities, let us now determine respective two continuity equations. *Div*-operation applied to (2) gives these two equations, via the sums of respective middle terms:

$$\nabla\cdot\mathbf{J} = Q\,\nabla\cdot\mathbf{V} + \mathbf{V}\cdot\nabla Q = -\,\partial_t Q \,, \tag{3a}$$

$$\nabla\cdot\mathbf{A} = \varepsilon\mu\,(\Phi\,\nabla\cdot\mathbf{V} + \mathbf{V}\cdot\nabla\Phi) = -\varepsilon\mu\,\partial_t\Phi\,. \tag{3b}$$

Dilatations and *convections* of the two static, form respective kinetic quantities. The static potential carried by respective charge behaves as a rigid structure, of the homogeneous speed. The former terms thus annul, with the convective derivatives ($\mathbf{V}\cdot\nabla = -\partial_t$) – in the latter terms. Of course, it is opposite to the moving gradient.

In analogy with Bernoulli's effect in fluids, two parallel flows interact by transverse kinetic forces, and crosswise ones – by respective torques [4]. Both these interactions, conditioned by the transverse gradient or *curl* of the kinetic potential (2b), are represented by magnetic field (4a). On the other hand, its own *curl* will be soon identified as the total current field (4b), situated in the conducting and dielectric structural layers.

$$\mathbf{B} = \nabla\times\mathbf{A}\,, \qquad\qquad \nabla\times\mathbf{H} = \mathbf{J} + \partial_t\mathbf{D}\,. \tag{4}$$

Similarly to the static relations, each new member of the three kinetic quantities is the formal feature of preceding one. The total magnetic, depends on respective vacuum field and the medium density: $\mathbf{B} = \mu\mathbf{H}$. Magnetic field, as the intermediate quantity, is perpendicular to the other two, usually mutually collinear, kinetic quantities.

Alike the relations (2) of the carriers or potentials, two fields, as the intermediate quantities, can be similarly related. The substitution of (2b) into (4a) gives:

$$\mathbf{B} = \varepsilon\mu(\Phi\,\nabla\times\mathbf{V} - \mathbf{V}\times\nabla\Phi) = \mu\,\mathbf{V}\times\mathbf{D}\,, \qquad\qquad \mathbf{H} = \mathbf{V}\times\mathbf{D}\,. \tag{5}$$

At motion of rigid, stably oriented static quantities, the former middle term annuls. In accord with (1a), the latter term gives the kinetic convective relation (5b). A moving electric, forms respective magnetic field, determining the transverse kinetic forces. *Curl* applied to (5b), excluding spatial derivatives of the field speed, gives (4c):

$$\nabla\times\mathbf{H} = \mathbf{V}\,\nabla\cdot\mathbf{D} - \mathbf{V}\cdot\nabla\mathbf{D} = \mathbf{J} + \partial_t\mathbf{D}\,. \tag{6}$$

Here $\mathbf{V}\,\nabla\cdot\mathbf{D} = \mathbf{V}Q = \mathbf{J}$ is the current of free electricity, and $\mathbf{V}\cdot\nabla\mathbf{D} = -\partial_t\mathbf{D}$ – the convective derivative of electric displacement, or respective current.

3.2 Relative Phase

The latter phase of the kinetic interactions concerns the actions of kinetic fields upon moving punctual objects. Namely, apart from the kinetic fields, the forces also depend on the object motion. The kinetic interaction of the two kinetic potentials or respective currents, at least in their parallel position, may be expressed by the two equivalent (nominally – static, but in fact – kinetic) quantities, the potential and respective charge:

$$\Phi_{\mathrm{k}} = -\mathbf{v}\cdot\mathbf{A}\,, \qquad\qquad Q_{\mathrm{k}} = -\varepsilon\mu\,\mathbf{v}\cdot\mathbf{J}\,. \tag{7}$$

This pair of equations is formally inverse to the definitions (2), with the opposite signs, and the product $\varepsilon\mu$ – consequently replaced. They concern only the parallel motion, but speak nothing about the torque between the two crosswise currents. Negative signs point to the transverse attraction in the parallel motion. *Grad* applied to (7a), without spatial derivatives of the object speed, gives the equivalent (kinetic) electric field:

$$\mathbf{E}_{\mathrm{k}} = \mathbf{v}\times\nabla\times\mathbf{A} + \mathbf{v}\cdot\nabla\mathbf{A} = \mathbf{v}\times\mathbf{B}\,. \tag{8}$$

The longitudinal gradient of the unidirectional potential equals to its divergence. In the case of two moving charges, with the divergence (3b) of the kinetic potential, the latter term thus tends to equalize the two speeds, forming the torque acting on a 'dipole' consisting of the two charges moving at the different speeds. In the case of a line current, with longitudinal homogeneity of the kinetic potential ($\nabla\cdot\mathbf{A} = 0$), the latter term annuls.

At transverse object speeds, when $\nabla\mathbf{A} = \nabla\times\mathbf{A} = \mathbf{B}$, the two terms (8) cancel each other, in accord with the defective sense of (7). Therefore, the latter term must be finally missed. The remaining term causes a torque tending to the same courses of the two crosswise currents. *Div* operation applied to (8) gives the equivalent charge:

$$Q_{\mathrm{k}} = \varepsilon(\mathbf{B}\cdot\nabla\times\mathbf{v} - \mathbf{v}\cdot\nabla\times\mathbf{B})\,. \tag{9}$$

The zero charge value just expresses the circular motion of a free object charge around the magnetic field, represented by *curl* of the object speed – in the former term. At rectilinear motion – this term annuls, and the letter term returns to (7b).

4. DYNAMIC RELATIONS

With respect to the reactive medium, time derivative of the kinetic potential, as the linear momentum, gives the dynamic forces, expressed by electric field:

$$\mathbf{E} = -\partial_t\mathbf{A}\,, \qquad \nabla\times\mathbf{E} = -\partial_t\mathbf{B}\,. \tag{10}$$

Curl operation applied to (10a), with respect to (4a), gives (10b). On the other hand, *div* applied to (4a) gives the trivial Maxwell's equation: $\nabla\cdot\mathbf{B} = 0$. It only speaks against existence of free magnetic poles and respective non-vortical field.

The kinetic potential and magnetic field are the two perpendicular vortical fields, and their gradient is perpendicular to their common surface. The motion in this direction varies them at a resting point, with production of the dynamic field (10a):

$$\mathbf{E} = -\partial_t\mathbf{A} = \mathbf{U}\cdot\nabla\mathbf{A} = \mathbf{B}\times\mathbf{U}\,. \tag{11}$$

Here $\mathbf{U}$ is the transverse speed of the kinetic potential and magnetic field, restricted to the field line plains, with: $\nabla\mathbf{A} = \nabla\times\mathbf{A} = \mathbf{B}$. Really, in the inverse mathematical sense, *curl* applied to the external equality of (11) just gives (10b):

$$\nabla\times\mathbf{E} = \mathbf{U}\cdot\nabla\mathbf{B} - \mathbf{U}\nabla\cdot\mathbf{B} = -\partial_t\mathbf{B}\,. \tag{12}$$

The speed derivatives of the rigid magnetic field – stably oriented in space – are missed. Magnetic field moving along its gradient, in its own field line planes, induces the dynamic forces (11), represented by respective electric field.

5. DIFFERENTIAL SET

5.1 Basic Equations

The three differential pairs – static (1), kinetic (4) and dynamic (10) – taken together form the two subsets, known as *gauge conditions* (13) and *Maxwell's equations* (14). In analogy with electric displacement current – in (14b), the left term of (14c) may be considered as some magnetic displacement current. The former set thus defines the three fields by respective potentials, and latter – the carriers by their fields. In other words, the fields are the formal features of respective potentials, and the carriers – of the fields.

$$\mathbf{E}_\mathrm{s} = -\nabla \Phi \,, \qquad \mathbf{B} = \nabla \times \mathbf{A} \,, \qquad \mathbf{E}_\mathrm{d} = -\partial_t \mathbf{A} \,; \tag{13}$$

$$Q = \nabla \cdot \mathbf{D} \,, \qquad \mathbf{J} + \partial_t \mathbf{D} = \nabla \times \mathbf{H} \,, \qquad \partial_t \mathbf{B} = -\nabla \times \mathbf{E} \,. \tag{14}$$

Owing to their distinct origins, static and dynamic fields demand respective indexes (13a,c). With respect to their geometric forms, these indexes are excessive in (14a,c). By its physical nature, the displacement current in (14b) understand both field components. Unlike the former EM theory, founded on electricity and its currents, the two potentials appear as the most relevant EM quantities. Describing the energetic states of the medium, they are the starting notions in this axiomatic presentation of EM theory.

The three pairs of the equations concern mutual differential relations of the quantities on respective three kinematical states – static, kinetic and dynamic – being dependent on the presence, motion or acceleration, respectively, of the three static quantities. Apart from the two potentials, time derivative of the kinetic potential may be taken as the dynamic potential. Neglecting the trivial relation, $\nabla \cdot \mathbf{B} = 0$, three relevant Maxwell's equations, in common with respective gauge conditions, form the hierarchical trinity.

5.2 Field Tensors

The two pairs of Maxwell's equations (static & kinetic with trivial & dynamic) in their componential forms represent two sets of the four partial differential equations each. With general ordinal indexation, they form respective tensor equations:

$$\Sigma_n \partial_n R_{mn} = J_m \,, \qquad \Sigma_n \partial_n F_{mn} = 0 \,. \tag{15}$$

Here $m = 0,1,2,3$ is the ordinal number of the equations, with the summation of the terms per the index $n \neq m$. The electric charge carried by the cosmic expansion along temporal axis forms respective current component (J_o). In the absence of the free magnetic poles and respective currents, the latter equation fails in the free term. The field components are identified by the following tensors, as the bi-vectors:

$$R_{mn} = \begin{bmatrix} 0 & +D_x & +D_y & +D_z \\ -D_x & 0 & +H_z & -H_y \\ -D_y & -H_z & 0 & +H_x \\ -D_z & +H_y & -H_x & 0 \end{bmatrix}, \qquad F_{mn} = \begin{bmatrix} 0 & -B_x & -B_y & -B_z \\ +B_x & 0 & -E_z & +E_y \\ +B_y & +E_z & 0 & -E_x \\ +B_z & -E_y & +E_x & 0 \end{bmatrix}. \tag{16}$$

They express the vortices of all components, the former – of the rational $(R_{mn} = D,H)$, and latter – of force fields $(F_{mn} = B,E)$. Their artificial distinction, as contra-variant & variant, is neglected. The six term pairs accord to the six planes, as the field locations. The first rows and columns concern longitudinal planes (tx , ty , tz) – in the temporal, and remaining subtensors – transverse planes (xy , yz , zx) – in spatial domains. Owing to the opposite signs of respective terms, these two tensors cannot be dually related.

Each of them affirms 4D space, as the ambient of EM phenomena. The opposite positions of the rational and force fields point to the two structural levels: electric and magnetic ones. With respect to the apparent – electric, and transparent magnetic poles, the former tensor is more relevant. Therefore, EM potentials, forming 4D vector, belong to the four axes: static to t , and kinetic to x , y , z . The field carriers, as a tri-vector, belong to respective three 3D subspaces. The projection into 3D reduces t-axis into scalar time, and respective electric quantities (from tr-planes) lose this one dimension.

5.3 Derived Equations

Apart from the three relevant Maxwell's equations and respective gauge conditions, relating the successive ranks of EM quantities, the carriers and potentials can be related directly, by the two Riemannian, second order differential equations:

$$\varepsilon\mu\, \partial_t^2 \Phi - \nabla^2 \Phi = Q/\varepsilon \,, \qquad \varepsilon\mu\, \partial_t^2 \mathbf{A} - \nabla^2 \mathbf{A} = \mu \mathbf{J} \,. \tag{17}$$

With respect to (3b), (14a) applied to the sum of (13a,c) relates the two electric quantities, charge and static potential (17a). With respect to (2b), (17a) multiplied by $\varepsilon\mu\mathbf{V}$ gives (17b). The temporal terms accord to dynamic, and spatial – to static electric fields. Maxwell's equations understand both electric fields $(\mathbf{E}_s + \mathbf{E}_d)$, speaking in favour of their unity in tr-planes. At the dielectric media, without free electricity and current, these two reduce into respective wave equations, with the known solution: $r = t/\sqrt{\varepsilon\mu} = \mathrm{c}t$.

The moving fields carry their energies. Dot multiplication of the kinetic Maxwell's equation by $\mathbf{E}$, and of dynamic one – by $\mathbf{H}$, with subtraction of the latter from former results, gives a 5D continuity equation, with the *spatial*, *temporal* and *substantial* terms. As such, it affirms a structural dimension, as the fifth. EM phenomena thus develop in and/or between the four structural layers: *vacuum*, *dielectric*, *magnetic* & *conducting* ones.

$$\nabla \cdot (\mathbf{E} \times \mathbf{H}) + \partial_t W + \mathbf{E} \cdot \mathbf{J} = 0 \,, \qquad \mathbf{S} = \mathbf{E} \times \mathbf{H} = \mathbf{D} \times \mathbf{B} \mathrm{c}^2 \,. \tag{18}$$

The equation (18a) is well-known as Poynting's theorem. Its temporal term expresses the variation of energy density, and substantial one, $\mathbf{E} \cdot \mathbf{J} = \mathbf{F} \cdot \mathbf{V}$, – the power of its dissipation. This term may be understood as the energy dislocation along the fifth axis, from one into another structural layers. Cross product of the two fields, in the spatial term, represents the current $(\mathbf{S})$ of EM energy (18b). According to Einstein's equation, the product of the two total fields is equivalent with the linear momentum density.

6. ALGEBRAIC SET

6.1 Basic Equations

The algebraic relations, derived from differential ones, may be considered as the basic set (19). The associated total fields, moving in common with their carriers, produce the dissimilar vacuum fields (a,b): *transverse motion of one, produces the other EM field*. Apart from thus obtained electric field (b), affecting all present electricity – in the field direction, the magnetic field (a) acts kinetically on the moving electricity or electric current, by the magnetic, – or equivalent electric field (c). And finally, two EM fields, mutually causally related in (a/b), form the energetic current (d), perpendicular to the related fields.

$$\mathbf{H} = \mathbf{V} \times \mathbf{D}\,, \qquad \mathbf{E} = \mathbf{B} \times \mathbf{U}\,, \qquad \mathbf{E}_k = \mathbf{v} \times \mathbf{B}\,, \qquad \mathbf{S} = \mathbf{E} \times \mathbf{H}\,. \tag{19}$$

Though formally similar, the two relations (a,b) are distinctly restricted. With respect to the differential elaboration, a field motion is effective only along the field gradient. Unlike non-vortical fields, generally inhomogeneous in any direction, the gradients of vortical fields are restricted to the field line planes. Excluding electro-static fields, this restriction concerns both – magnetic and electro-dynamic moving fields.

The simplest technical basis, convenient for the measurement and consideration, is the motion and mutual affection of the line, current carrying and object – conductors. The free electrons and their electric fields, moving along a conductor, form magnetic field (a). This is the case irrespective of the resting protons and their associated fields, compensating only statically the moving fields. Transverse motion of the carrying conductor, in the planes of magnetic field lines, causes the longitudinal induction (b). In fact, the moving field gradient changes the field in the observed locations, with the inductive reaction of the medium. The similar effect arises around a variable current, as accelerated electricity, causing the circular magnetic field, expanding or shrinking radially. These contractions cause the longitudinal inductions in parallel conductors, including carrying conductor itself.

On the other hand, the relative relation (c) is effective in any direction – transverse to the magnetic field. A parallel object conductor – moving transversally – suffers the longitudinal induction, and vice versa. Two parallel currents thus attract, and anti-parallel repel each other. Consequently, by such interactions of their adjacent legs, two crosswise conductors tend to the same courses of their currents. A punctual object charge is thus compelled to the circular motion, around a tube of the present magnetic field.

The two convective relations (a,b) were initially emphasized by J. J. Thomson. With respect to the neglected spatial derivatives of the field speeds, during their derivation – from the differential set, this pair is restricted to the rigid moving fields stably oriented in space. The moving fields form the gyroscopes in common with the apparent elementary carriers. In the absence of this explanation, the two convective relations seemed to be nearly problematic. In spite of their simple forms and practical evidences, they have so far been neglected in the standard presentations of EM theory, as possible basic laws.

6.2 Derived Equations

Above basic relations are combined in some practical situations. In the case of two parallel conductors, one of them with its free electricity, and the other with its current and magnetic field (19a), moving transversally – along the field gradient, the dynamic (19b) and kinetic (19c) inductions superimpose (20). On the basis of this case, the principle of relativity is understood, calculating by the mutual speed: $\mathbf{v}' = \mathbf{v} - \mathbf{U}$. However, in the case of the two crosswise conductors, at motion along the current, in the direction of the field homogeneity, the dynamic induction (19b) fails, and (20) is reduced to (19c).

$$\mathbf{E}_{kd} = (\mathbf{v} - \mathbf{U}) \times \mathbf{B}\,. \tag{20}$$

In the case of dielectric media, without free electricity and conduction currents, the two moving fields may form EM wave only. The substitution of (19a) into (19b), or vice versa, gives (21a/b). Their former terms concern the collinear speeds of the two transverse EM fields. The latter terms express the boundary region of the wave beam, with the longitudinal direction of one of the two fields. With respect to the energetic current (19d), these terms express transverse expansion or diffraction of the wave beam.

$$\mathbf{E} = \varepsilon\mu[(\mathbf{U}\cdot\mathbf{V})\mathbf{E} - (\mathbf{E}\cdot\mathbf{U})\mathbf{V}], \qquad \mathbf{H} = \varepsilon\mu[(\mathbf{U}\cdot\mathbf{V})\mathbf{H} - (\mathbf{H}\cdot\mathbf{V})\mathbf{U}]. \tag{21}$$

The kinetic interaction of the two moving punctual or distributed charges is achieved by the production of magnetic field – at motion of one, and action of this field on the other moving charge. In this sense, (19a) substituted into (19c) gives:

$$\mathbf{E}_{\mathrm{k}} = \mu[(\mathbf{v}\cdot\mathbf{D})\mathbf{V} - (\mathbf{v}\cdot\mathbf{V})\mathbf{D}]. \tag{22}$$

The double cross product resolves the interaction into the two vector components: *axial* and *radial* ones. Though both obey the force symmetry, $\mathbf{E}_{\mathrm{k}}(-\mathbf{r}) = -\mathbf{E}_{\mathrm{k}}(\mathbf{r})$, the axial interaction would produce some torque on a moving dipole consisting of the two mutually connected charges. In fact, the above made substitution implicitly understood the resting magnetic field of a moving charge. Its possible motion is taken into account by substitution of (19a) into (20), thus obtaining the adequate, more complex equation:

$$\mathbf{E}_{\mathrm{kd}} = \mu[(\mathbf{v}-\mathbf{U})\cdot\mathbf{D}]\,\mathbf{V} - \mu[(\mathbf{v}-\mathbf{U})\cdot\mathbf{V}]\mathbf{D}. \tag{23}$$

The zero torque on a dipole moving at the common speed $(\mathbf{V} = \mathbf{v})$ is satisfied by the zero axial term, and this one – by the *transverse* field speed, $U = V\cot\theta$, where θ is the polar angle between moving electric field and its speed. Magnetic field lines expand in the front, and shrink behind the carrying charge. This result can be interpreted and confirmed by the transverse convective derivative of a moving central potential:

$$U = \frac{\partial y}{\partial t} = -\frac{\partial y}{\partial x}\frac{\partial x}{\partial t} = \frac{x}{y}V = V\cot\theta. \tag{24}$$

As in (3), the convective derivative is opposite to the moving gradient, where $\partial y/\partial x = -x/y$ is the derivative of a moving circle: $x^2 + y^2 = r^2$. The transverse gradient of a moving static potential (2b) is nothing else than magnetic field (13b).

The moving fields carry by themselves their energies. In this sense, the substitution of (19a/b) into (19d) gives two respective energetic currents:

$$\mathbf{S}_{\mathrm{e}} = (\mathbf{E}\cdot\mathbf{D})\mathbf{V} - (\mathbf{V}\cdot\mathbf{E})\mathbf{D}, \qquad \mathbf{S}_{\mathrm{m}} = (\mathbf{H}\cdot\mathbf{B})\mathbf{U} - (\mathbf{U}\cdot\mathbf{H})\mathbf{B}. \tag{25}$$

Their former terms express the two main currents, and two latter – accessory ones, exist in respective physical processes. In the case of EM waves, these terms have the same roles as respective terms of (21). In the open causal processes, with only one moving field, one of the two equations (25) is applied. Around a moving punctual charge, with the transverse motion of its magnetic field (24), the latter term of (25b) annuls.

7. CENTRAL LAWS

7.1 Static Relations

Elementary EM interactions are caused by the *presence*, *motion* and *acceleration* of the punctual charges. At first, the application of the static equation (14a) to a punctual carrying charge (q_1) gives the force acting on a similar object (q_2), or vice versa. One of the charges thus affects the other, in accord with the *static central law*:

$$\mathbf{f}_{\mathrm{s}} = n\,\mathbf{r}_{\mathrm{o}}/\varepsilon\mu = n\mathrm{c}^2\mathbf{r}_{\mathrm{o}} , \qquad n = \mu\, q_1 q_2/4\pi r_{1,2}^2 . \qquad (26)$$

The factor n simplifies the equations and eases their comparison. Radial integration of this force gives respective potential energy, expressed by the *alternative static law* (27), with the elementary factor $m = nr$ – of *induction* or *self-induction*:

$$w = m/\varepsilon\mu = m\mathrm{c}^2 , \qquad m = \mu\, q^2/4\pi r . \qquad (27)$$

This is Einstein's equation, with the factor (m) – of self-induction, as the *proper* mass. The condition of the two laws (9a,10a) equivalence, the relation (10b) is the basis for calculation of the particle radius. It thus expresses the proper particle mass, where r is its radius, as the distance of the *surface charge* from its own centre.

With respect to (27b), *a lesser charged particle is of the greater mass and energy, and vice versa.* This fact points to indispensable location of the mass and energy in the surrounding electric field. If this mass were equivalent to the *inertial* mass, a complex – globally neutral – body, as the structural multi-pole, would manifest the resultant summary mass of all its constituent poles. Owing to cancelation of the distant fields of the opposite poles in the multi-pole, this sum is slightly *defected*. There is very difficult to believe that possibly exists some another cause of the inertial mass and respective forces.

7.2 Kinetic Relations

The substitution of the transverse speed of magnetic field (24) into the combined force (23) gives the combined force resolved into the following three terms:

$$\mathbf{f}_{\mathrm{kd}} = nV[(v_{\mathrm{t}}\,\mathbf{i}_{\mathrm{l}} - v_{\mathrm{l}}\,\mathbf{i}_{\mathrm{t}})\,sin\,\theta - V cos\,\theta\,\mathbf{i}_{\mathrm{l}}] . \qquad (28)$$

The two former components represent the kinetic force (19c) acting on an object charge moving through the resting magnetic field. Apart from the carrier, it also depends on the object motion, or of a detector substituting the object. In the case of the two parallel speeds $(v_{\mathrm{t}} = 0)$, it reduces into the transverse force component:

$$\mathbf{f}_{\mathrm{kd}} = -nV(v\,sin\,\theta\,\mathbf{i}_{\mathrm{t}} + V cos\,\theta\,\mathbf{i}_{\mathrm{l}}) . \qquad (29)$$

The last force component, of the dynamic field (11) – directed towards the moving charge, from both axial sides – is independent of the object speed or of respective detector. Affecting all present charges, it looks as an associated wave period. Subtracted from the static field – extracted from (26), it gives the *ellipsoidal* field deformation, initially somehow predicted by H. A. Lorentz, without a needed causal explanation.

Radial integration of (29) gives the *mutual kinetic* energy (30). In such the ellipsoidal form, this energy depends on the angle of integration.

$$w = -mV(v\,sin^2\theta + V cos^2\theta)\ . \qquad (30)$$

In the case of the equal speeds of the field carrier and its object, the force (29) and energy (30) reduce into respective, *centrally symmetric* forms:

$$\mathbf{f} = -n(\mathbf{V}\cdot\mathbf{v})\,\mathbf{r}_o\ , \qquad w = -m\,\mathbf{V}\cdot\mathbf{v}\ . \qquad (31)$$

Though mutually equal – in this particular case, the two speeds keep their distinct roles, concerning the carrier or object. Apart from the force symmetry, this case also satisfies the zero torque on a moving dipole. The comparison with (26a,27a) identifies the static laws as the particular cases of these ones, at the speed ic – of all the particles. This analogy points to a common motion along temporal axis, possibly related with the cosmic expansion. The imaginary unit (i) points to some circulation in tr- planes.

7.3 Mass Function

Affecting in return the carrier itself (at $\mathbf{V} = \mathbf{v}$ thus understood), the combined central force (31a) is subtracted from the static force (26). Thus obtained total force is evenly distributed about the particle surface, forming the even pressure:

$$f_{\mathrm{tot}} = n(\mathrm{c}^2 - v^2) = n\mathrm{c}^2(1 - v^2/\mathrm{c}^2) = n\mathrm{c}^2 g^2\ . \qquad (32)$$

Factor n directly depends on the radius, and g – on speed. Tending to zero approaching the speed c, from $f_o = n_o\mathrm{c}^2$, where $n_o = n(r_o)$ – at rest, this force strives to expand the particle. This is prevented by the opposite reaction of the *polarized medium*, the same as at rest. The balance ($f = f_o$) gives the two following relations:

$$r = r_o g\ , \qquad m = m_o/g\ . \qquad (33)$$

The latter of them is nothing else but Lorentz' *mass function*, estimated on the empirical bases. It is here derived directly, by the simple theoretical procedure. Thus dependent on speed, mass is minimal when resting in a *preferred* frame! This frame, as the basis for the speed determination, is somehow related with the medium [4].

The mass function (33b) further confirms the above reduction of inertia to induction. As such, it was the known basis for indirect derivation of Einstein's equation (27a). According to the mass function, there just follows its differential (34a). The further formal procedure gives the *proper kinetic energy* of a moving (charged) particle:

$$\partial m = mv\partial v/(\mathrm{c}^2 - v^2)\ , \qquad \mathrm{c}^2\partial m = mv\partial v + v^2\partial m : \qquad (34)$$

$$\partial w_k = p\partial t = vf\partial t = v\partial(mv)\ , \qquad v\partial(mv) = mv\partial v + v^2\partial m = \mathrm{c}^2\partial m\ ; \qquad (35)$$

$$w_k = w - w_o = (m - m_o)\mathrm{c}^2\ , \qquad w - w_o = q^2(1/r - 1/r_o)/4\pi\varepsilon\ . \qquad (36)$$

Assuming the constant mass $(\partial m = 0)$, with annulment of the latter term in (35b), the former term integral gives the classical kinetic energy $(mv^2/2)$. The complete integral gives (36a). The substitution of (27b) relates the kinetic energy with that of the electric field between the two radii, – of the moving and resting particle (36b).

7.4 Dynamic Relations

Variation in time of the kinetic energy may be caused by some acceleration or deceleration of the carrier. In this sense, time derivative of (31b), partially – per mV, gives the *power* of the energy transfer – on the left of (37a). The two speeds of the same particle concern its two roles: of the field carrier (qV) and object (qv).

$$\partial_t w_k = \mathbf{v}\cdot\partial_t(m\mathbf{V}) = -\mathbf{v}\cdot\mathbf{f}_\mathrm{d}\,, \qquad \mathbf{f}_\mathrm{d} = -\partial(m\mathbf{V})/\partial t\,. \tag{37}$$

On the other hand, the same power equals to the negative scalar product of the object speed and *reactive* dynamic force – in the continuation. The reduction finally gives the *force action law* (37b), in the function of *variable* mass and its acceleration.

With respect to (33b) and its derivative (34a), the dynamic force can be further elaborated, treating the linear momentum as the product of the three factors:

$$\partial_t(mv\mathbf{v}_\mathrm{o}) = v\mathbf{v}_\mathrm{o}\partial_t m + m\mathbf{v}_\mathrm{o}\partial_t v + mv\,\partial_t\mathbf{v}_\mathrm{o}\;. \tag{38}$$

Here v is the speed modulus, and $\mathbf{v}_\mathrm{o}$ – unit vector. The two former terms are transformed into *inertial*, and latter one gives the known *centrifugal* force:

$$\mathbf{f}_\mathrm{i} = -v\frac{\partial m}{\partial v}\frac{\partial v}{\partial t}\mathbf{v}_\mathrm{o} - m\frac{\partial v}{\partial t}\mathbf{v}_\mathrm{o} = -\frac{m}{g^2}\frac{\partial v}{\partial t}\mathbf{v}_\mathrm{o}\,, \tag{39}$$

$$\mathbf{f}_\mathrm{c} = -mv\frac{\partial\mathbf{v}_\mathrm{o}}{\partial t} = -mv\frac{\partial\mathbf{v}_\mathrm{o}}{\partial s}\frac{\partial s}{\partial t} = \frac{mv^2}{r}\mathbf{r}_\mathrm{o}\,. \tag{40}$$

Here $\mathbf{r} = r\mathbf{r}_\mathrm{o}$ is the path curvature radius. Both force components are additionally scaled, by the variable mass. Instead of the two *different masses* estimated empirically, there are in fact the two distinct *functions* of the same *variable mass*.

The former force changes the energy of the moving body, and latter one only strives to strait motion. The former of them may be understood as the difference of the opposite *dynamic* forces from (29), being unequal at acceleration. On the other hand, the transverse direction of the centrifugal force, and its independence of the linear acceleration, point to its *kinetic* nature. The terms ‘static, kinetic & dynamic’ are here used in the relative senses, dependent on the observed objects and respective levels of observation.

8. CONCLUSIONS

1. EM quantities and standard differential equations are introduced in the axiomatic order, starting from the static potential and its linear motion. 2. The four algebraic relations are thus reaffirmed, re-examined and prepared for application. 3. By the magnetic field motion, the general kinetic law is finally formulated. 4. The central laws firmly mutually relate a number

of independent former results: Coulomb's law, Einstein's equation, classical radius with EM mass, EM induction, force action law, inertial with centrifugal forces, mass function, mass defect, associated wave and ellipsoidal field deformation. 5. The three sets supplement each other in the interpretations and applications. 6. The principle of relativity and assumption of elementary mass are convincingly called in question.

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Note: The above references represent the former development and wider context. Their own references may be also taken into account. In the final instance, as being fully deductive, the presented article is self-sufficient, irrespective of the references.