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Systematic Foundation of EM Theory

Branko Mišković

Independent, Novi Sad, Serbia

Abstract Two so far partially used alternative basic sets – algebraic relations and central laws – are completed and related with the standard differential equations. The senses and ranges of validities of all the equations are examined. The dual conception of the two fields is gradually transferred into the scientific system of radial – static, transverse – kinetic, and longitudinal – dynamic elementary forces, dependent on mutual distance, simultaneous motion and acceleration of interacting charges. The extended EM theory, more systematic than its standard presentations, is obtained and affirmed.

Keywords EM theory, Algebraic relations, Central laws, Differential equations

1. Introduction

Between various physical quantities, the three main pairs of them are used as the basic notions of physics: length & time – as the *kinematical*, mass & charge – as *substantial*, and force & energy – as *interactive* quantities. A particular physical discipline mathematically relates these quantities – by respective laws. The *necessary and sufficient number of mutually independent laws represents the basic set*, as the formal basis of the theory. Apart from their own internal *consistencies* and empirical *evidences*, these equations are expected to obey some *operative advantages*, convenient for consistent methodical *foundation*, transparent *exposition* and convincing *acceptance* of the theory. *A minimal number of – as simple as possible – equations, directly presenting fundamental physical relations, is wanted*.

Apart from Maxwell's equations and gauge conditions – in the *differential* forms, some EM quantities are related *algebraically*. On the other hand, *central laws* determine directly elementary interactions of two punctual charges, in the functions of their kinematical relations: mutual position, simultaneous motion and acceleration of at least one of them. However, some equations of the two latter basic sets have not been so far formulated in general, nor the ranges of their application were precisely determined. Though do not obey perfectly all the operative advantages, Maxwell's equations play the role of the basic set. In spite of their wide successful application, a number of nearly forgotten empirical results are still waiting for adequate explanations.

In the aim of the final formulation and further elaboration of the two incomplete basic sets, they are here consistently derived and convincingly explained. The ranges of their successful applications are also determined. On their bases, the interpretation of some of the mentioned problematic empirical results are finally obtained. All this is achieved systematically, by mutual relation and support in derivation of the three basic sets. After constitution of the theory, a way of a simple introduction of the *algebraic set* is presented. They support the derivation of *central laws*, and these ones – of *differential equations*. Apart from thus enabled systematic foundation and exposition of the theory, the three basic sets – supplementing each other in applications, give many-sided insight into the physical relations.

* Corresponding author:
aham.brami@gmail.com (Branko Mišković)
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2. Scientific Methodology

Physical science, as the conscious image of reality, relies its development on the two pairs of the sources or criteria of cognition: *empirical* & *formal* – as objective, and *rational* & *intuitive* – as subjective. Apart from passive *observation*, the empirical phase consists of some *experimental* procedures, performed by respective instruments. In the formal phase, the empirical facts are *classified* and mutually *related* by the verbal, logical or mathematical expressions. In the sense of further confirmation of the formal results, their convenient rational *interpretations* demand sufficiently clear *visions* of the physical processes. Of course, this phase is founded on the analogies with the former knowledge and experience. Some intuitive ideas of the researches enable their own *orientation* in the process of investigation.

With respect to the *sensory* and *mental* limitations, the two former sources are usually supported by respective technical equipments. Their results are thus regarded as objective, as if independent of the human arbitrariness. However, in spite of this respect, these results are nearly senseless without some rational interpretations. In addition, the scientific procedures are inevitably directed by the personal intuitive expectations. Unfortunately, in the opposition to the mentioned objective supports, and also – in possible relation with them, the two subjective criteria are in the same ratio suppressed. Instead of them, the non-scientific criterion of *authority* of the former scientists and their texts is crucial in the modern physics. Actual deficit of the subjective criteria is tried to compensate by the long lists of cited references.

Each of the four criteria may be the primary source, which result must not contradict to anyone of them. Consulting the subjective criteria, *inductive elaboration* of a theory starts by the two objective sources, from natural phenomena, towards their deeper essences. If the theory disobeys at least one of the criteria, its origins must be re-examined. Otherwise, it may be accepted as adequate. With respect to the imperfect sources or criteria, some readiness for its re-examination must be kept. Of course, the order of the criteria application need not be inductive. Convincing presentation of a theory demands its *deductive exposition*, starting from the achieved or expected its essence, towards practical applications. The deductive procedures may correct possible inconsistencies or mistakes of the inductive elaboration.

These general conditions and respective procedures are at least implicitly applied and thus presented in this *systematic foundation* of the fundamentals of EM theory. The *inductive elaboration* of the three basic sets is exposed in the sections 3-6, from EM phenomena – towards their relation and explanation. It is also related with the former investigation of this topic, by formal derivation and rational interpretation of the known ideas and results, but without wider theoretical implications. Starting from the essence of EM phenomena, in the form of the convenient analogies, the inverse *deductive exposition* of thus advanced theory is consistently presented in the sections 7-10. With convincing confirmation of the main algebraic relations, their elementary *applications* are briefly presented in the sections 11-14.

3. Constitution of EM Theory

3.1. Introduction of EM Fields

Two EM *fields*, *electric* ($\mathbf{E}$) and *magnetic* ($\mathbf{B}$), were initially noticed as the actions upon respective dipoles: $\mathbf{p}$ & $\mathbf{m}$. Each of the fields exclusively affects its own dipole, by some *torque* and/or *force difference*:

$$\mathbf{t}_e = \mathbf{p} \times \mathbf{E}\,,\ \ \delta\mathbf{f}_e = \mathbf{p} \cdot \nabla\mathbf{E}\,; \tag{1}$$

$$\mathbf{t}_m = \mathbf{m} \times \mathbf{B}\,,\ \ \delta\mathbf{f}_m = \mathbf{m} \cdot \nabla\mathbf{B}\,. \tag{2}$$

The two dipoles, as the objects, can be induced by these fields, on respective material scrapings. The torques direct the dipoles into the field courses, and the forces draw them into the domains of the stronger fields. These two pairs of interactions mathematically express the primary introduction of the two EM fields. Thus symmetric, electric and magnetic phenomena seemed to be mutually independent.

This symmetry is disturbed in the experience. Unlike an electric dipole, $\mathbf{p} = q\mathbf{r}$, constituted of the two opposite poles – structurally connected on some mutual distance $(\mathbf{r})$, the magnetic moment cannot be split into separate poles. Instead, it can be obtained by rotation of an electric dipole around one of its two poles: $\mathbf{m} = \mathbf{r} \times q\mathbf{v}$. The two EM dipoles are thus mutually related and reduced to *electricity*, as a bipolar substance – in respective kinematical states.

3.2. Rational Fields

The field carriers and their objects are expressed by the *substantial* field of electricity, $Q = \partial q/\partial v$, as some volume density of one of its two polarities, unlike electric *charge*, as the difference of the two polarities. On the other hand, the *kinematical fields* – of a distance, speed and acceleration – represent these three quantities in the functions of their position in space. Algebraic combination of the two field types gives the derived – *rational fields*. Apart from the *current field*, $\mathbf{J} = Q\mathbf{V}$, as a moving electric polarity, volume densities of respective dipoles represent the two *material* fields, *polarization* and *magnetization*:

$$\mathbf{P} = Q\mathbf{R}\,,\ \ \mathbf{M} = \mathbf{P} \times \mathbf{V}\,. \tag{3}$$

The two kinematical fields $(\mathbf{R}\ \&\ \mathbf{V})$ here represent the arranged sets of respective elementary quantities. However, the initial dipoles cause the two mutually opposite *reactions* of the surrounding media: $\mathbf{d} = -\mathbf{p}$ & $\mathbf{h} = \mathbf{m}$. Their volume densities form the two *associated fields*: $\mathbf{D}$ & $\mathbf{H}$. These two fields continue respective material causes, in the *opposite* or *circular* directions, respectively. In fact, they represent some medium *disturbances* and their *motion*.

3.3. Force Fields

With respect to electricity, as the common objective bases, the two above mentioned force fields should be redefined. Unlike the *general force field*, $\mathbf{F} = \partial\mathbf{f}/\partial v$, as some volume density of many elementary forces, the *specific force fields* – electric $(\mathbf{E})$ and magnetic $(\mathbf{B})$ – express their own actions upon respective *unit punctual* objects:

$$\mathbf{f}_e = q\mathbf{E}\,,\ \ \mathbf{f}_m = q\mathbf{v} \times \mathbf{B}\,. \tag{4}$$

Electricity and its motion are the new objects. Of course, these two relations are accommodated with the two EM fields being already introduced. The latter of them is applied to moving electricity, as the object. The *electric* forces are collinear with respective field, but the cross product points to the transverse direction of the *magnetic* forces – to both, object speed and respective field. The former symmetry is disturbed by the united objective basis.

3.4. Constitutive Relations

The similar fields in the two pairs of definitions – rational associated to (3) and force fields (4) – are mutually related in practice, by respective *EM constants*:

$$\mathbf{D} = \varepsilon_o\mathbf{E} + \mathbf{P} = \varepsilon\mathbf{E}\,, \tag{5a}$$

$$\mathbf{B} = \mu_o(\mathbf{H} + \mathbf{M}) = \mu\mathbf{H}\,. \tag{5b}$$

Apart from the medium features, the constants determine the quantities and units. These two roles are separated by the factorization: $\varepsilon = \varepsilon_o \varepsilon_r$, $\mu = \mu_o \mu_r$. The two *vacuum factors* harmonize the quantities and units, and *relative* ones express the intrinsic features of the present material media. The *cross* classification of the two field pairs is thus obtained. Namely, the two *vacuum* components $(\mathbf{E} \,\&\, \mathbf{H})$ cause respective two *total* fields $(\mathbf{D} \,\&\, \mathbf{B})$ – at material media.

EM processes take part in the four structural layers of the complex material media: *vacuum*, *dielectric*, *magnetic* and *conducting* ones. First of them concerns the free space and *vacuum fields*. Two next layers are substrata of respective two *material* components: polarization and magnetization. The asymmetric relations (5) point to the distinct structural levels of the two EM forces. As if, electric forces act from vacuum only, but magnetic ones concern the material layer too. Dimensional equalling of respective fields, by the unit vacuum factors – expressed in natural units, turns these two equations into formally symmetric shapes.

4. Algebraic Relations

4.1. Convective Relations

The associated total fields, moving in common with their carriers, produce respective dissimilar vacuum fields. The two *convective relations*, describing these processes, were initially emphasized by J. J. Thomson:

$$\mathbf{H} = \mathbf{V} \times \mathbf{D}\,, \;\; \mathbf{E} = \mathbf{B} \times \mathbf{U}\,. \tag{6}$$

Here $\mathbf{V}$ is speed of electric, and $\mathbf{U}$ – of magnetic fields; (6a) obviously follows from (3b), and (6b) – from experience. These relations may be also commonly verbally expressed: *transverse motion of one, produces the other EM field*. The field symmetry, as if reaffirmed by these two equations, will be disturbed in the further consideration.

With respect to the cross-products, the speeds transverse to respective field lines are understood. However, there are also some asymmetric restrictions of the two relations (6). The differential treatment points that *respective motion is effective only along the field gradient.* Unlike a *non-vortical* moving field, generally inhomogeneous in any direction, the gradient of a *vortical* field is usually restricted to the field line planes. A *static* (non-vortical) electric field, in principle moving in (6a), is producing the vortical magnetic field. This field itself moving in the field line planes would produce the *dynamic* (vortical) electric field (6b).

The simplest technical basis, convenient for measurement and consideration, is the motion and mutual affection of current carrying line conductors. Transverse motion of such a conductor, in the magnetic field line planes, causes some longitudinal induction (6b). The moving field gradient changes the field in the observed locations, with respective inductive reaction of the medium. The similar effect arises around a variable current, as the accelerated electricity, causing respective circular magnetic field, expanding or shrinking radially. These transverse field contractions cause respective longitudinal inductions, in all parallel conductors, including the carrying conductor itself.

4.2. Relative Relations

The obtained fields (6) interact with *similar* present fields. As if, the present fields act directly onto *moving dissimilar* objects, by some *equivalent fields*, according to following – *relative algebraic relations*:

$$\mathbf{E}_{eq} = \mathbf{v} \times \mathbf{B}\,, \;\; \mathbf{H}_{eq} = \mathbf{D} \times \mathbf{u}\,. \tag{7}$$

The field carriers from (6) are here treated as the moving objects. Therefore, here $\mathbf{v}$ is the speed of electricity, and $\mathbf{u}$ – of the magnet or respective current carrying conductor. Substituted magnetic, by equivalent electric force (4) gives (7a), with analogous relation (7b). The equivalent fields just represent the two dissimilar forces: (7a) *magnetic* and (7b) *electric*. The former force is collinear, and tatter transverse, to respective equivalent field. In the absence of free magnetic poles, (7a) only is usually used.

Unlike the relation (6b), restricted to motion in the field line planes, the object speed in (7a) is effective in the both directions in relation to magnetization current, as the field cause: *longitudinal* motion produces *transverse* induction, and vice versa. By respective transverse forces, two parallel current carrying conductors attract, and anti-parallel ones – repel each other. Consequently, by such interactions of their perpendicular legs, two crosswise conductors tend to the same courses of their two currents. And finally, a free moving charge is compelled to the circular motion around so called tubes of the present magnetic field.

4.3. Mutual Relations

Irrespective of the force natures, nominally similar fields from (6) & (7) formally add, giving the *effective* interactions of the two dissimilar moving entities:

$$\mathbf{E}_{ef} = (\mathbf{v} - \mathbf{U}) \times \mathbf{B}\,, \tag{8a}$$

$$\mathbf{H}_{ef} = (\mathbf{V} - \mathbf{u}) \times \mathbf{D}\,. \tag{8b}$$

In fact, these two equations describe the same pair of dissimilar forces; only the roles of the carrier and object are opposite. The former of them is usually used. With respect to the mutual (object-field) speed, the *principle of relativity* is understood [1]. However, owing to restricted validity of the convective component, this principle must be restricted to the motion in the field line planes. In fact, the two distinct (magnetic and electric) – mutually opposite – interactions are superimposed in this particular case.

The motion *perpendicular* to the field line planes can be practically tested by the known Faraday's experiments, in the simple form consisting of a rotational conducting disc and permanent magnet [2]. An instrument is connected by sliding contacts between the centre and rim of the conducting disc, rotating in the front of cylindrical magnet, around their common axis. The implicit magnetization current, flowing on the magnet cover, interacts with free electricity of the disc, rotating in parallel. The kinetic interaction of the two parallel currents looks as some radial induction in the disc, expressed by the equivalent electric field (7a).

However, the same or simultaneous rotation of the magnet does not produce any inductive effect, thus confirming the restriction of the relativity principle. For the sake of this principle, some physicists believe that the circular motion of the magnetic field – perpendicularly to the field line planes – would produce respective static field, according to (6b). In other words, a magnetization or conduction current, moving with the carrier – in its own direction, would produce some electric charge. In the observed case, however, the two circuit parts (disc radius and external cable) would suffer the two opposite thus assumed inductions.

The same signal in the circuit arises after reconnection of the sliding contacts to the rotating magnet itself. In fact, the magnet now takes over the former role of the disc. Its moving free electrons interact kinetically with magnetization current – on the magnet cover, in the same manner as at the separate rotating disc. Also in this case, the assumed induced charge and respective non-vortical field could not cause any circular current in the observed electric circuit.

5. Central Laws

5.1. Static Laws

Elementary EM interactions are caused by the *presence*, *motion* and *acceleration* of punctual charges. First of all, in analogy with gravitation, a charge affects all other charges in accord with the *static* (Coulomb's) *law*:

$$\mathbf{f}_s = n\mathbf{r}_o/\varepsilon\mu = nc^2\mathbf{r}_o\,,\ \ n = \mu q_1 q_2/4\pi r_{1,2}^2\,. \qquad (9)$$

The factor n simplifies the equations and enables their comparison. Radial integration of this force gives the energy, expressed by the *alternative static law*, with the new factor $m = nr$, as the *mutual* or *proper* mass:

$$w = m/\varepsilon\mu = mc^2\,,\ \ m = \mu q^2/4\pi r\,. \qquad (10)$$

The alternative law, by its form – at least, represents the well-known Einstein's equation. As the condition of the two laws (9a) & (10a) equivalence, the relation (10b) was the basis for calculation of the 'classical' electron radius. This relation thus expresses the proper mass of a single charged particle, where r is the particle radius, as the distance of the *surface charge* from its own centre.

The mutual and proper masses are in fact the elementary factors of *induction* and *self-induction*, respectively. With respect to (10b), *a lesser charged particle is of the greater proper mass and energy, and vice versa.* This fact points that the mass and energy are located in the surrounding fields. If this one be equivalent with *inertial* mass, a complex globally neutral body, as the structural multi-pole, will manifest the resultant summary mass of all its constituent charge particles. Owing to cancelation of the distant fields of the opposite poles in the multi-pole, this sum is slightly *defected*. There is difficult to believe that really exists some another cause of the inertial mass and respective forces.

5.2. Field Motion

Apart from the above static interactions of the present electric charges, two moving charges interact by additional – *kinetic* forces. In this sense, the substitution of (6a) into (7a) gives the following equivalent field:

$$\mathbf{E}_{eq} = \mu[(\mathbf{v}\cdot\mathbf{D})\mathbf{V} - (\mathbf{v}\cdot\mathbf{V})\mathbf{D}]\,. \qquad (11)$$

Thus obtained field consists of the two components: the former – *axial*, and latter – *radial*. Though both satisfy the force symmetry, i. e. $\mathbf{E}(-\mathbf{r}) = -\mathbf{E}(\mathbf{r})$, the axial interaction would form some torque on a moving dipole, even in the case of a fixed mutual position of the two interacting charges, at $\mathbf{V} = \mathbf{v}$. Not only that this formal result calls in question the action-reaction symmetry, but the predicted torque has not been noticed in Trouton-Noble experiment. Therefore, the equation (11) must be re-examined. In fact, the above made substitution implicitly understood the resting magnetic field around a moving charge, what cannot be even imagined. Instead of the application of (7a), some inevitable motion of this field is taken into account by the application of (8a), thus obtaining the effective electric field:

$$\mathbf{E}_{ef} = \mu[(\mathbf{v}-\mathbf{U})\cdot\mathbf{D}]\,\mathbf{V} - \mu[(\mathbf{v}-\mathbf{U})\cdot\mathbf{V}]\mathbf{D}\,. \qquad (12)$$

However, there arises the question of the speed $\mathbf{U}$ of the magnetic field (25b) around a moving charge. Apart from unacceptable field rest, its longitudinal motion, together with the two commonly moving interacting charges, would annul their interaction (12). There remains the supposition of some *transverse* field motion. At a common speed of the carrier and object $(\mathbf{V} = \mathbf{v})$, the condition of zero axial interaction and its torque (in the former term) gives:

$$V\cos\theta - U\sin\theta = 0\,,\ \ U = V\cot\theta\,. \qquad (13)$$

Here θ is the polar angle. *Magnetic field lines spread in the front, and shrink behind a moving charge*. As this speed is independent of the object motion, the result (13) is general. With respect to the transverse speed direction, the remaining (latter) term of (12) turns into the central form (17a). In the case of the different speeds of the two particles, when one of them overtakes the other, some torque may be expected. In fact, this would be a *rotational* motion of the 'dipole', with *acceleration* or *deceleration* of its poles.

The infinite speed value – at the zero polar angle – can be explained by the following interpretation of the magnetic field and its motion. A static central potential (26a), moving along x-axis, is changing convectively – in direction y. With respect to the circle equation, $x^2 + y^2 = r^2$, and to its derivative, $\partial y/\partial x = -x/y$, there follows:

$$U = \frac{\partial y}{\partial t} = -\frac{\partial y}{\partial x}\frac{\partial x}{\partial t} = \frac{x}{y}V = V\cot\theta\,. \qquad (14)$$

With respect to (27b), transverse gradient of the kinetic potential (26b) is nothing else than magnetic field (25b). This field is not a substantial quantity, but the formal feature of the potential. This may be generalized to all fields.

5.3. Kinetic Laws

In the interesting simpler case – of the two parallel speeds, the substitution of the transverse speed (14) into (12) gives the transverse *magnetic*, and longitudinal *electric* forces, of the *kinetic* and *dynamic* fields (49), respectively:

$$\mathbf{f} = -nV(v\sin\theta\,\mathbf{i}_t + V\cos\theta\,\mathbf{i}_l) = q(\mathbf{E}_k + \mathbf{E}_d)\,. \quad (15)$$

The former force component represents the known kinetic interaction of two moving charges, as the parallel convection currents. Apart from the carrier, it depends on the motion of the object or respective field detector.

The latter force component, as the dynamic field directed towards the moving charge – from both its axial sides, does not depend on the object motion (v). In other words, it is invariant of the reference frame (connected to the detector). Affecting all present charges, it looks as an associated wave period. Subtracted from the static field (25a) – extracted from (9), it causes the *ellipsoidal* field deformation. This effect was somehow predicted by H. A. Lorentz [3], but without a needed causal explanation.

Radial integration of the forces (15) gives *mutual kinetic* energy. In such ellipsoidal – *axially symmetric* – form, this energy depends on the angle of integration:

$$w = -mV(v\sin^2\theta + V\cos^2\theta)\,. \quad (16)$$

In the case of the equal speeds of the field carrier and its object $(\mathbf{V} = \mathbf{v})$, the force (15) and energy (16) reduce into respective *centrally symmetric* forms:

$$\mathbf{f} = -n(\mathbf{V}\cdot\mathbf{v})\,\mathbf{r}_o\,, \;\; w = -m\mathbf{V}\cdot\mathbf{v}\,. \quad (17)$$

Apart from the force symmetry, this case also satisfies the zero torque on a moving dipole. The comparison with (9a & 10a) identifies the static laws as the particular cases of these two kinetic laws, at the speed $i\mathrm{c}$ – of all the particles. This analogy points to a common motion along temporal axis, possibly related with cosmic expansion. The imaginary unit points to some circulation in tr-planes.

5.4. Mass Function

Affecting – in return – the carrier itself (at $\mathbf{V} = \mathbf{v}$ thus understood), the combined central force (17a) is subtracted from the static force (9). Thus obtained total force is evenly distributed about the particle surface:

$$f_{\mathrm{tot}} = n(\mathrm{c}^2 - v^2) = n\mathrm{c}^2(1 - v^2/\mathrm{c}^2) = n\mathrm{c}^2 g^2\,. \quad (18)$$

The factor n 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. Therefore, it must be opposed by supposed *constant external pressure*, the same as at rest. The balance ($f = f_o$) gives the two following relations:

$$r = r_o g\,, \;\; m = m_o/g\,. \quad (19)$$

The latter of them is nothing else than Lorentz' *mass function* [3], estimated on 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, as the reference of the speed determination.

The constant external pressure on the particle surface can be ascribed to the *vacuum medium pressure*, similar to that in the usual material fluids. In the same sense, the dynamic force in (15) may be interpreted as some acceleration and compression of the medium – in the front, and the opposite processes – behind a moving charge.

The mass function further confirms the above reduction of the inertia to induction. As such, it was the known basis for initial indirect derivation of Einstein's equation (10a). With respect to the mass differential, $\partial m = mv\partial v/(\mathrm{c}^2 - v^2)$ or $\mathrm{c}^2\partial m = mv\partial v + v^2\partial m$, there follows the *proper kinetic energy* of a moving (charged) particle:

$$\partial w_k = p\partial t = vf\partial t = v\partial(mv)\,, \quad (20a)$$

$$v\partial(mv) = mv\partial v + v^2\partial m = \mathrm{c}^2\partial m\,; \quad (20b)$$

$$w_k = w - w_o = (m - m_o)\mathrm{c}^2\,, \quad (20c)$$

$$w - w_o = q^2(1/r - 1/r_o)/4\pi\varepsilon\,. \quad (20d)$$

Assuming the constant mass $(\partial m = 0)$, with annulment of the latter term in (20b), the former term integral gives the classical kinetic energy $(mv^2/2)$. The complete integration of (20a,b) gives (20c). The substitution of (10b) relates the kinetic energy with that of the static field between the two radii, of the moving and resting particle.

5.5. Dynamic Law

Variation in time of the kinetic energy is caused by some acceleration or deceleration of the carrier. In this sense, time derivative of (17b), partially – per mV, gives the *power* of the energy transfer – on the left of (21a). Though mutually equal, the two speeds of the same particle concern its two roles: of the carrier (qV) and object (qv).

$$\partial_t w_k = \mathbf{v}\cdot\partial_t(m\mathbf{V}) = -\mathbf{v}\cdot\mathbf{f}_d\,, \quad (21a)$$

$$\mathbf{f}_d = -\partial_t(m\mathbf{V})\,. \quad (21b)$$

On the other hand, the same power equals to the negative scalar product of the object speed and *reactive* dynamic force – in the continuation of (21a). The reduction finally gives the *force action law* (21b), in the function of the *variable* mass and its linear and/or transverse acceleration.

Taking into account (19b), the dynamic force (21b) can be further elaborated, by derivation of the linear momentum, as the product of the three following factors:

$$\partial_t(mv\mathbf{v}_o) = v\mathbf{v}_o\partial_t m + m\mathbf{v}_o\partial_t v + mv\partial_t\mathbf{v}_o\,. \quad (22)$$

Here v is the speed modulus, and $\mathbf{v}_o$ – unit vector. With the mass derivative, $\partial m/\partial v = mv/(\mathrm{c}^2 - v^2)$, the two former terms give *inertial*, and latter one – *centrifugal* forces:

$$\mathbf{f}_\mathrm{i} = -v\frac{\partial m}{\partial v}\frac{\partial v}{\partial t}\mathbf{v}_\mathrm{o} - m\frac{\partial v}{\partial t}\mathbf{v}_\mathrm{o} = -\frac{m}{g^2}\frac{\partial v}{\partial t}\mathbf{v}_\mathrm{o}, \quad (23a)$$

$$\mathbf{f}_\mathrm{c} = -mv\frac{\partial \mathbf{v}_\mathrm{o}}{\partial t} = -mv\frac{\partial \mathbf{v}_\mathrm{o}}{\partial s}\frac{\partial s}{\partial t} = \frac{mv^2}{r}\mathbf{r}_\mathrm{o}. \quad (23b)$$

Here $\mathbf{r} = r\mathbf{r}_\mathrm{o}$ is the path curvature radius. Both forces are additionally scaled – by the variable mass. Instead of the two *different masses* estimated empirically [3], there are the two distinct *functions* of the same *variable mass*.

The former force changes the energy of the moving body, and latter one strives to the strait motion. The former of them may be understood as the difference of two opposite *dynamic* forces from (15), being unequal at acceleration. In this sense, the transverse direction of the centrifugal force (23b) and its independence of the linear acceleration, point to its *kinetic* (magnetic) nature. The terms 'static, kinetic & dynamic' are here used in the relative senses, dependent on the observed object and respective level of consideration.

6. Differential Equations

6.1. Maxwell's Equations

By gradual generalization of the central fields – extracted from respective laws, the three *relevant* Maxwell's equations – *static*, *kinetic* and *dynamic* – are obtained:

$$\nabla\cdot\mathbf{D} = Q, \quad (24a)$$

$$\nabla\times\mathbf{H} = \mathbf{J} + \partial_t\mathbf{D}, \quad (24b)$$

$$\nabla\times\mathbf{E} = -\partial_t\mathbf{B}. \quad (24c)$$

The current field in (24b) consists of the *convection* and *conduction* components – in the former, and *displacement* one – in the latter terms. The remaining (*trivial*) Maxwell's equation, $\nabla\cdot\mathbf{B} = 0$, only speaks against existence of free magnetic poles and their non-vortical fields, possibly predicted in advance. Let us now announce the procedures for derivation of the three relevant equations (24), starting from respective central forces or fields.

The static law (9) is resolved into electric field definition (4a) and its central distribution in the space around punctual carrying charge (25a). Obviously, this field is evenly distributed about each concentric sphere, with the full field flux through each such sphere, just equal to the charge q. As *Gaussian theorem*, this equality is generalized to each closed surface embracing some distributed charge. Further generalized mathematically by Maxwell, this theorem is expressed in the differential form (24a).

$$D = q/4\pi r^2 = \varepsilon E, \quad (25a)$$

$$H = qV\sin\theta/4\pi r^2 = B/\mu. \quad (25b)$$

With respect to relation (6a), the moving central electric (25a), gives the circular magnetic field (25b). This result is well-known as *Ampere's theorem*. Convenient integration of the sequence of such fields along an infinite line conductor gives the magnetic field distribution: $H = I/2\pi\rho$, where $I = \partial q/\partial t$ denotes the line current or respective flux, and ρ – cylindrical radius. The field integral along a closed contour embracing the current just gives (24b).

Magnetic field is thus determined by electric current, as some motion of electricity. Therefore, the increasing field understands accelerated motion. With respect to the dynamic law (21b) and mass-charge relation (10b), this acceleration is opposed by the inertial forces, as dynamic field described by (24c). Otherwise, this equation is introduced on the empirical bases, as Faraday's 'static' induction.

With respect to the formal senses of *div* & *curl* operations, there may seem that (24a) concerns the static, and (24c) – dynamic components only, in the non-vortical and vortical forms, respectively, irrespective of the applied symbols, as the total electric field: $\mathbf{D} = \varepsilon\mathbf{E} = \varepsilon(\mathbf{E}_\mathrm{s} + \mathbf{E}_\mathrm{d})$. However, with respect to its physical sense, the displacement current $(\partial_t\mathbf{D})$ in (24b) concerns both field components.

6.2. Gauge Conditions

The integration of the forces (9a&17a) gave the energies (10a&17b) respectively. Alike the fields – as specific forces, the two potentials – *static* and *kinetic* – as specific energies, are extracted from the obtained energies:

$$\Phi = q/4\pi\varepsilon r, \quad \mathbf{A} = \mu q\mathbf{V}/4\pi r. \quad (26)$$

At least the two former of the three gauge conditions (27) obey the comparison of the central fields (25) and respective EM potentials (26). Really, the negative *radial* derivative of (26a) directly gives (25a). In the similar way, *transverse* derivative of the *unidirectional* kinetic potential (26b) gives the magnetic field (25b). Its direct substitution into (24c), with conditional cancelation of the *curl*-operators, finally gives the *dynamic* gauge condition (27c).

$$\mathbf{E}_\mathrm{s} = -\nabla\Phi, \quad (27a)$$

$$\mathbf{B} = \nabla\times\mathbf{A}, \quad (27b)$$

$$\mathbf{E}_\mathrm{d} = -\partial_t\mathbf{A}. \quad (27c)$$

The origins of the two electric fields are distinct, and so their symbols demand respective indexes. Instead of the above confirmations, the three equations (27) were at least tacitly postulated as the *gauge conditions*.

The comparison of the two potentials (26) relates them algebraically (28a). Respective continuity equation (28b) was formulated intuitively by L. Lorentz.

$$\mathbf{A} = \varepsilon\mu\Phi\mathbf{V}, \quad \nabla\cdot\mathbf{A} = -\varepsilon\mu\partial_t\Phi. \quad (28)$$

Alike the field relation (6a), (28a) similarly expresses the kinetic, by motion of static potentials. Each of the equations (28), and both in common, point to possible fluid-mechanical interpretation of all EM phenomena [4].

7. Static Relations

With respect to above indications, let a *subtle omnipresent* medium – *compressible*, *super-fluidic* and *inert* – be taken as the substantial essence of space, including the particles, as its disturbances. Say that this medium is denser around positive, and sparser around negative poles. Tending to the medium homogeneity, two equipolar particles mutually repel, and opposite ones attract each other.

The *compressibility* (ε) of the medium is the basis of the static effects, dependent on the distances of interacting poles. The *super-fluidity* and *mass density* (μ) maintain continual fluid flows, with kinetic and dynamic effects, dependent on their motion and acceleration. The product of the elasticity, density and pressure disturbance gives the disturbed density $(\varepsilon\mu\Phi)$, and its motion forms *linear momentum density* $(\mathbf{A})$. In analogy with material media, the two constants determine the known speed of wave propagation, $\mathrm{c}^2 = 1/\varepsilon\mu$, otherwise obtained from the wave equation.

Irrespective of its cause, permanently disturbed pressure of a fluid is possible in a closed volume only. In free space, however, it would diffuse into surroundings. Therefore, the compressible fluid is to be substituted by the solid, *dielectric*, *non-resistive* and *reactive* medium, with respective roles of the three new features. In balance with the opposite structural forces, the medium *polarization* is elastically restricted. The non-resistance enables the smooth displacement of the static quantities through the medium, with the kinetic and dynamic effects. The reactivity – as the basis of induction – is indeed a more general notion than the inertia itself.

The strain of the polarized medium, as the *static potential*, is in direct relation with electric energy density. Each of such central disturbances, as an elementary potential, provides the energy for all other such disturbances, as the *objects*. This potential directly determines the *static field* (29a), and this field itself – *carrying charge* (29b):

$$\nabla\Phi = -\mathbf{E}_{\mathrm{s}}, \quad \nabla\cdot\mathbf{D} = Q. \qquad (29)$$

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

8. Kinetic Relations

8.1. Convective Relations

Medium *non-resistance* enables the smooth displacement of the static quantities through space. In parallel with the *current field* (30b), respective motion of the static *potential*, as the *pressure disturbance*, forms the *kinetic* potential (30a), similar to *linear momentum density*:

$$\mathbf{A} = \varepsilon\mu\Phi\mathbf{V}, \quad \mathbf{J} = Q\mathbf{V}. \qquad (30)$$

The product of *elasticity*, *reactivity* and *strain disturbance*, gives the equivalent *density disturbance*. Moving charges and their potentials form the two collinear kinetic quantities, the potential and electric current. At motion of the negative static quantities, the kinetic ones are opposite.

The kinetic is determined by motion of static potentials. Let us now strictly derive their differential relation. Namely, *div*-operation applied to (30a) gives the condition (28b), via the sum of the two terms in the middle:

$$\nabla\cdot\mathbf{A} = \varepsilon\mu\,(\Phi\,\nabla\cdot\mathbf{V} + \mathbf{V}\cdot\nabla\Phi) = -\varepsilon\mu\,\partial_t\Phi. \qquad (31)$$

The *dilatation* and *convection* of the static, form kinetic potentials. Following its own elementary carriers, the static potential behaves as a rigid structure, of homogeneous speed. The former term thus annuls, with the *convective derivative*, $\mathbf{V}\cdot\nabla = -\partial_t$, in the latter term. Of course, this derivative is opposite to the moving field gradient.

In analogy to Bernoulli's effect, two parallel flows interact by the transverse *kinetic* forces, and crosswise ones – by the torques. These interactions, determined by the transverse gradient or *curl* of the linear momentum density (30a), are represented by *magnetic field* (32a). On the other hand, its own *curl* will be soon identified as total current field (32b), in the three electrical structural layers.

$$\nabla\times\mathbf{A} = \mathbf{B}, \quad \nabla\times\mathbf{H} = \mathbf{J} + \partial_t\mathbf{D}. \qquad (32)$$

The latter term in (32b), as displacement current, concerns the derivatives of both, static and dynamic field components. Magnetic field, as the intermediate quantity, is perpendicular to the other two, collinear kinetic quantities.

Alike the pair (30) relating the potentials or carriers, the two fields, as intermediate quantities, can be similarly related. The substitution of (30a) into (32a) gives:

$$\mathbf{B} = \varepsilon\mu(\Phi\nabla\times\mathbf{V} - \mathbf{V}\times\nabla\Phi), \quad \mathbf{H} = \mathbf{V}\times\mathbf{D}. \qquad (33)$$

At rectilinear motion of the rigid static potential, the former term in (33a) annuls. In accord with (29a), the latter term gives the *kinetic convective relation* (33b). *A moving electric, produces magnetic field,* causing transverse kinetic forces. In the inverse sense, *curl* applied to (33b), excluding the derivatives of the field speed, gives (32b):

$$\nabla\times\mathbf{H} = \mathbf{V}\nabla\cdot\mathbf{D} - \mathbf{V}\cdot\nabla\mathbf{D} = \mathbf{J} + \partial_t\mathbf{D}. \qquad (34)$$

Here $\mathbf{V}\nabla\cdot\mathbf{D} = \mathbf{V}Q = \mathbf{J}$ is convection and/or conduction electric current, and $\mathbf{V}\cdot\nabla\mathbf{D} = (\mathbf{V}\cdot\nabla)\mathbf{D} = -\partial_t\mathbf{D}$ – convective derivative of the field, or displacement current.

8.2. Relative Relations

Apart from the *carrier*, the kinetic forces also depend on *object* motion, and thus demand the relative relations. The interaction of 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:

$$\Phi_{\mathrm{k}} = -\mathbf{v}\cdot\mathbf{A}, \quad Q_{\mathrm{k}} = -\varepsilon\mu\,\mathbf{v}\cdot\mathbf{J}. \qquad (35)$$

These two relations concern the parallel flows, but speak nothing about the torque between two crosswise currents. This pair is formally inverse to (30), with the opposite signs and the product $\varepsilon\mu$ consequently replaced. Negative signs point to the transverse attraction of the parallel flows. *Grad* applied to (35a), without spatial derivatives of the object speed, gives the equivalent electric field:

$$\mathbf{E}_\mathrm{k} = \mathbf{v}\times\nabla\times\mathbf{A} + \mathbf{v}\cdot\nabla\mathbf{A} = \mathbf{v}\times\mathbf{B}. \qquad (36)$$

Longitudinal gradient – in the latter term – equals to the divergence. In the case of two moving charges, with the divergence (31) of the kinetic potential, this term tends to equalize the two speeds. This is the cause of the torque acting on a dipole consisting of two interacting charges moving at different speeds. In the case of a line electric current, with longitudinal homogeneity of the kinetic potential ($\nabla\cdot\mathbf{A} = 0$), the latter middle term of (36) annuls.

At transverse object speed, when $\nabla\mathbf{A} = \nabla\times\mathbf{A} = \mathbf{B}$, the two terms cancel each other, in accord with defective sense of (35). Thus, the latter term must be missed. *Div* applied to the former term gives respective charge:

$$Q_\mathrm{k} = \varepsilon\nabla\cdot\mathbf{E}_\mathrm{k} = \varepsilon(\mathbf{B}\cdot\nabla\times\mathbf{v} - \mathbf{v}\cdot\nabla\times\mathbf{B}). \qquad (37)$$

The zero equivalent charge – at right side, points to the rotational motion of a free object charge around a magnetic field tube, here expressed by the *curl* of the object speed – in the former term. At rectilinear motion this term annuls, and the letter term gives (35b). This effect is also manifest as the torque between two crosswise currents (in the pairs of their adjacent legs), tending to the same courses.

9. Dynamic Relations

Due to the reactive medium, time derivative of the linear momentum density gives some *dynamic* forces, represented by respective electric field:

$$\partial_t\mathbf{A} = -\mathbf{E}_\mathrm{d}, \qquad \partial_t\mathbf{B} = -\nabla\times\mathbf{E}. \qquad (38)$$

Curl applied to (38a), with respect to (32a), gives (38b). Since $\nabla\times\mathbf{E}_\mathrm{s} = \mathbf{0}$, index is excessive in (38b). *Div* applied to (32a) gives the *trivial* equation: $\nabla\cdot\mathbf{B} = 0$.

The potential $\mathbf{A}$ and field $\mathbf{B}$ are the two perpendicular vortical fields, with gradient perpendicular to the common surface. The motion in this direction convectively varies the potential at a resting point, and – with respect to (38a) – produces the longitudinal *dynamic* field:

$$\mathbf{E} = -\partial_t\mathbf{A} = \mathbf{U}\cdot\nabla\mathbf{A} = \mathbf{B}\times\mathbf{U}. \qquad (39)$$

Here $\mathbf{U}$ is the *transverse* speed of the field and potential, restricted to the field line plains, where $\nabla\mathbf{A} = \nabla\times\mathbf{A} = \mathbf{B}$. Really, in the inverse mathematical sense, *curl* applied to the external equality of (39) gives (38b):

$$\nabla\times\mathbf{E} = \mathbf{U}\cdot\nabla\mathbf{B} - \mathbf{U}\nabla\cdot\mathbf{B} = -\partial_t\mathbf{B}. \qquad (40)$$

The speed derivatives of the *rigid* field – *stably oriented* in space – are missed. There is the known result: *magnetic field moving in its own field line planes induces dynamic forces*, represented by respective electric field.

With respect to (35), a punctual charge moving along a current carrying conductor, suffers transverse kinetic forces (36). Irrespective of (39), this conductor moving in its own direction does not cause any inductive effect.

The *kinetic* (33) and *dynamic* (39) relations just represent the convective Thomson's pair (6). With respect to the above procedures, neglecting spatial derivatives of the field speeds, this pair is restricted to the *uniform rectilinear* motion. These two relations thus seemed to be problematic. In spite of their simple forms and practical evidences, they have so far been tacitly missed from the standard EM theory.

10. Field Tensor

The *static* and *kinetic* equations (24a,b) in componential forms represent the set of the four partial differential equations. With the general ordinal indexation, this set is expressed by the following tensor equation:

$$\Sigma_n \partial_n R_{mn} = J_m. \qquad (41)$$

Here $m = 0,1,2,3$ is the ordinal number of the equations, with the summation of their terms per the index $n \neq m$. The electric charge carried by the known cosmic expansion along temporal axis forms respective current component (J_0). The *rational* field components ($R_{mn} = D, H$) are identified by the following tensor, as a bi-vector:

$$R_{mn} = \begin{bmatrix} 0 & +D_x & +D_y & +D_z \\ -D_x & 0 & +H_z & -H_y \\ -D_y & -H_z & 0 & +H_x \\ -D_z & +H_y & -H_x & 0 \end{bmatrix}. \qquad (42)$$

This tensor expresses the field vortices of all components, and affirms 4D space, as the ambient of EM quantities. The six term pairs accord to the six planes, as the field locations. The first row and column concern the '*longitudinal*' planes (tx, ty, tz), with electric field. The remaining sub-tensor accords to '*transverse*' planes (xy, yz, zx), with magnetic field. EM potentials, as 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 space (xyz) reduces temporal axis into the usual scalar time, and respective electric quantities (from tr- planes) lose this one dimension.

A similar tensor equation is obtained from the *trivial* and *dynamic* Maxwell's equations. In absence of free magnetic poles, this equation lacks in the free term. The tensor now consists of the two force fields ($F_{mn} = E, B$). It concerns the *magnetic* level of observation or – of respective medium structure, with magnetic field in the longitudinal, and electric – in transverse planes of 4D space.

Apart from the three relevant Maxwell's equations (24), relating the fields with their carriers, and the three respective gauge conditions (27) – relating the potentials with the fields, – as the successive ranks of EM quantities, the carriers and potentials can be related directly, by the two Riemannian, second order differential equations:

$$\varepsilon\mu\,\partial_t^2\Phi - \nabla^2\Phi = Q/\varepsilon\,, \tag{43a}$$

$$\varepsilon\mu\,\partial_t^2\mathbf{A} - \nabla^2\mathbf{A} = \mu\mathbf{J}\,. \tag{43b}$$

With respect to the condition (31), the equation (29b) applied to the sum of (29a & 38a) relates the two electric quantities, the charge and static potential (43a). According to (29a), (43a) multiplied by the product $\varepsilon\mu\mathbf{V}$ just gives (43b). The temporal terms of these equations accord to *dynamic*, and spatial ones – to *static* electric fields. As if, Maxwell's equations understand both, *static* & *dynamic* electric fields, thus announcing their unity in tr- planes.

11. EM Energy

The volume densities of electric and magnetic energies at disturbed media are determined by the displacements of the two objects, in respective external fields:

$$\partial W_\mathrm{e} = \mathbf{F}\cdot\partial\mathbf{R} = Q\mathbf{E}\cdot\partial\mathbf{R} = \mathbf{E}\cdot\partial\mathbf{D}\,, \tag{44a}$$

$$\partial W_\mathrm{m} = (\mathbf{J}\times\mathbf{B})\cdot\partial\mathbf{R} = \mathbf{B}\cdot(\partial\mathbf{R}\times\mathbf{J}) = \mathbf{B}\cdot\partial\mathbf{H}\,. \tag{44b}$$

The objects (electricity & current) are displaced in electric and magnetic fields, respectively. The referent zeroes accord to the undisturbed media. In the pairs of the collinear similar fields, the dot products turn into ordinary ones. The simple integrals of the external terms thus finally give: $W_\mathrm{e} = ED/2$, $W_\mathrm{m} = BH/2$. At the complex material media these densities are distributed amongst the vacuum and respective material structural layers (45). Namely, the vacuum factors disturb the formal symmetry of these two equations.

$$\mathbf{E}\cdot\mathbf{D} = \mathbf{E}\cdot(\varepsilon_\mathrm{o}\mathbf{E} + \mathbf{P}) = \varepsilon_\mathrm{o}E^2 + PE\,, \tag{45a}$$

$$\mathbf{B}\cdot\mathbf{H} = \mu_\mathrm{o}(\mathbf{H} + \mathbf{M})\cdot\mathbf{H} = \mu_\mathrm{o}H^2 + \mu_\mathrm{o}MH\,. \tag{45b}$$

The moving fields carry their own energies. In this sense, 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 *spatial*, *temporal* and *substantial* terms:

$$\nabla\cdot(\mathbf{E}\times\mathbf{H}) + \partial_t W + \mathbf{E}\cdot\mathbf{J} = 0\,, \tag{46a}$$

$$\mathbf{S} = \mathbf{E}\times\mathbf{H} = \mathbf{D}\times\mathbf{B}\mathrm{c}^2\,. \tag{46b}$$

The equation (46a) is well-known as Poynting's theorem. Its temporal term expresses the energy density variation, and substantial one, $\mathbf{E}\cdot\mathbf{J} = \mathbf{F}\cdot\mathbf{V}$, – the power field of the energy dissipation. This term itself may be understood as the energy dislocation along fifth axis, from one into another structural layers. Cross product of the two fields, in the spatial term, represents the *current field* of EM energy (46b). According to Einstein's equation, the product of the two total fields is equivalent to the *linear momentum density*.

12. Moving Fields

Instead of the field variation – in the differential equations, algebraic relations treat their motion. A moving electric, thus gives magnetic field (47a), affecting other moving charges – by the equivalent electric field (47b):

$$H = \varepsilon V E_\mathrm{s}\,sin\,\theta\,, \qquad E_\mathrm{k} = -\,\varepsilon\mu\,vVE_\mathrm{s}\sin\theta\,. \tag{47}$$

Here θ is the polar angle between the moving field and its speed. The magnetic field is perpendicular to the plain of electric field and its motion. The longitudinal object motion gives transverse kinetic field, and vice versa.

On the other hand, with respect to (30a & 29a), the kinetic potential axially inhomogeneous as (28), moving in its own direction causes the *dynamic* induction:

$$\mathbf{E}_\mathrm{d} = -\partial_t\mathbf{A} = \mathbf{V}\cdot\nabla\mathbf{A} = -\,\varepsilon\mu E_\mathrm{s}V^2\cos\theta\,\mathbf{i}_\mathrm{l}\,. \tag{48}$$

Longitudinal motion of the kinetic potential is equivalent with transverse contraction of the magnetic field (14). The obtained dynamic field, independent of the object speed, is directed axially, towards the moving carrier (15). It reacts on the *increasing polarization of the medium – in the front, and decreasing – behind the moving charge*.

Transverse kinetic field (47b) affects the moving charges only, and dynamic one (48) – all the present charges. The moving charges are thus affected by their sum:

$$\mathbf{E}_\mathrm{k} + \mathbf{E}_\mathrm{d} = -\,\varepsilon\mu E_\mathrm{s}V(v\sin\theta\,\mathbf{i}_\mathrm{t} + V\cos\theta\,\mathbf{i}_\mathrm{l})\,. \tag{49}$$

In the resting frame $(v = 0)$, this is reduced to the letter term. In the frame of the object moving with carrier $(v = V)$, vector sum of the two components is subtracted from the moving static field, thus scaling this field:

$$\mathbf{E}_\mathrm{tot} = (1 - \varepsilon\mu v^2)\mathbf{E}_\mathrm{s} = g^2\mathbf{E}_\mathrm{s}\,. \tag{50}$$

This total field also affects – in return – the field carrier itself. The kinetic forces (47b), affecting the moving objects only, are scaled by the factor $h = 1 - \varepsilon\mu vV$.

Moving EM fields carry by themselves their energies. The convective relations (6), substituted into (46b), express the *electric* and *magnetic* energetic currents:

$$\mathbf{S}_\mathrm{e} = (\mathbf{E}\cdot\mathbf{D})\mathbf{V} - (\mathbf{V}\cdot\mathbf{E})\mathbf{D}\,, \tag{51a}$$

$$\mathbf{S}_\mathrm{m} = (\mathbf{H}\cdot\mathbf{B})\mathbf{U} - (\mathbf{U}\cdot\mathbf{H})\mathbf{B}\,. \tag{51b}$$

The former terms, as if – of the double energy densities – invariant of the field speeds, form the main currents, flowing at the field speeds. Therefore, the moving energies can be increased by extension of their spatial domains only. The two latter components flow along the moving fields: the carriers accept the energies in front, and release behind themselves, thus maintaining the moving amounts.

In the case of a charge moving with its fields, the latter term in (51b) annuls, owing to the perpendicular directions of the circular magnetic field and its transverse contraction.

The three remaining terms (52a) give (52b).

$$\mathbf{S} = (\mathbf{E}\cdot\mathbf{D})\mathbf{V} - (\mathbf{V}\cdot\mathbf{E})\mathbf{D} + (\mathbf{H}\cdot\mathbf{B})\mathbf{U}\,, \tag{52a}$$

$$\mathbf{S} = (\mathbf{V} - g^2\mathbf{U})ED\sin^2\theta\,. \tag{52b}$$

The relation (13a) – of the two field speeds $(\mathbf{U}\ \&\ \mathbf{V})$ – is also taken into account. The current is resolved into the two components, longitudinal & transverse. The apparent double value of the moving energy density (51a) is finally reduced to the former term (52b). In the function of the factor g, the latter term tends to zero towards $V = \mathrm{c}$.

13. EM Waves

Apart from the *longitudinal* medium undulation, its three features and respective kinetic forces maintain *transverse* oscillation too, perpendicularly to the kinetic potential. The *longitudinal* waves of electric currents in line conductors are followed by *transverse* waves of surrounding fields. The two mutually related waves are inseparable, with cyclic alternation and mutual support of their fields. At dielectric media, without free electricity and respective current, (43) reduce into respective wave equations, with the common solution: $r = \mathrm{c}t$, $\mathrm{c}^2 = 1/\varepsilon\mu$. The radius (r) just concerns the wave cross-section, by the plain of propagation.

With respect to Poynting's relation (46b), the speed of EM wave propagation equals to the ratio of the vacuum and total fields products, perpendicular to propagation:

$$\mathrm{c}^2 = EH/DB = W/M\,. \tag{53}$$

The field products express the flows of the wave energy and equivalent mass. Compared in natural units, this mass is equal or greater from the propagating energy.

With respect to closed causal loop of the wave propagation, magnetic field eliminated from (6) gives (54). At least in the transverse waves, the latter term annuls, thus reducing this equality into the conditional identity (55a).

$$\mathbf{E} = \varepsilon\mu[(\mathbf{U}\cdot\mathbf{V})\mathbf{E} - (\mathbf{E}\cdot\mathbf{U})\mathbf{V}]\,; \tag{54}$$

$$\mathbf{E} = \varepsilon\mu UV\mathbf{E}\,,\ UV = 1/\varepsilon\mu = \mathrm{c}^2\,. \tag{55}$$

The last result (55b) points to the two separate, possibly different speeds of the two fields, with the effective speed of the wave energy propagation, as their geometric average. At least in the case of the transverse fields in respective waves, the latter terms in (51) annul, and two former ones represent the same current of EM wave energy:

$$(\mathbf{E}\cdot\mathbf{D})\mathbf{V} = \mathbf{S} = (\mathbf{H}\cdot\mathbf{B})\mathbf{U}\,. \tag{56}$$

With expected equality of the vacuum energy densities (57a), this equation directly gives (57b), additionally relating the two field speeds. By help of their above product (55b), the two speeds are finally determined (58).

$$\varepsilon_o E^2 = \mu_o H^2\,,\ \varepsilon_r V = \mu_r U\,; \tag{57}$$

$$V = \mathrm{c}_o/\varepsilon_r\,,\ U = \mathrm{c}_o/\mu_r\,. \tag{58}$$

Substituted into (55b), they give the *refraction factor*, $\mathrm{n} = \mathrm{c}_o/\mathrm{c} = \sqrt{\varepsilon_r\mu_r}$, as the ratio of the two speeds (through vacuum and matter). The arithmetic average of the two sides of (56) explains the wave propagation:

$$S = \mathrm{c}_o(\varepsilon_o E^2 + \mu_o H^2)/2 = \mathrm{c}_o W_o\,. \tag{59}$$

This result points that the vacuum layer only transfers the wave energy, just at the standard speed c_o. Material layers temporarily retain respective fractions of the wave energy, thus increasing its density, and decreasing the effective speed of propagation. The separate speeds of the two fields (58) are the more *specific*, effective physical quantities.

14. Moving Media

Let us consider the processes around a third medium body moving in vicinity of the field carriers, through their external EM fields. These two fields statically induce material fields, *polarization* and/or *magnetization*:

$$\mathbf{P} = \mathbf{D} - \varepsilon_o\mathbf{E} = (1 - 1/\varepsilon_r)\mathbf{D} = \mathrm{j}\mathbf{D}\,, \tag{60a}$$

$$\mu_o\mathbf{M} = \mathbf{B} - \mu_o\mathbf{H} = (1 - 1/\mu_r)\mathbf{B} = \mathrm{k}\mathbf{B}\,. \tag{60b}$$

The asymmetry of the SI relations conceals the *fractional factors* j & k. The symmetry is better in the natural units $(\varepsilon_o = 1 = \mu_o)$. The incorrect Fresnel's factor formerly used, $\mathrm{f} = 1 - 1/\mathrm{n}^2$, is just reduced into one of these two factors, at exclusively dielectric or magnetic media.

The associated surrounding fields, moving in common with their carriers, produce dissimilar *convective* inductions, added to respective given fields:

$$\mathbf{H}' = \mathbf{H} + \mathrm{j}(\mathbf{u}\times\mathbf{D})\,,\ \mathbf{E}' = \mathbf{E} + \mathrm{k}(\mathbf{B}\times\mathbf{u})\,. \tag{61}$$

Here $\mathbf{u}$ is the moving medium speed. On the other hand, carrying the accumulated wave energies, the moving media also influence the wave propagation:

$$\mathbf{S}' = \mathbf{S} + (\mathrm{j}W_e + \mathrm{k}W_m)\mathbf{u} = \mathbf{S} + (W - W_o)\mathbf{u}\,. \tag{62}$$

Here $\mathbf{S}$ is the energetic current through resting, and $\mathbf{S}'$ – with moving medium. The two factors substituted into the former, give the latter result. This logical explanation just obeys the well-known Fizeau's result, with running water as the moving medium. Possible transverse speed component would distort the direction of propagation.

15. Summary

With respect to the moving entities – carrying & object *conductors*, charged *particles* and respective *disturbances* of the medium, three respective basic sets – *algebraic relations*, *central laws* and *differential equations* – are here introduced and mutually related. On the bases of the field definitions and respective empirical facts, the two algebraic pairs – *convective* & *relative* ones – are introduced, with further examination of their application. With the known – *static*, *kinetic* central law is formulated in its more general form, by help of the algebraic set. On their own bases, the *force action law* is identified as the *dynamic* law itself. With reduction of inertia to induction, the known mass function is derived and explained. Einstein's equation just appears as the alternative version of the static (Coulomb's) central law.

By mainly known generalizations of the central fields and respective energies, the three relevant Maxwell's equations and respective gauge conditions are introduced. With respect to the mutual relations of the two potentials, the analogous – dielectric – interpretation of EM phenomena is predicted and demonstrated. Starting from the static potential, with the electric *polarization* of the indispensable vacuum medium, the kinetic potential is interpreted as the linear momentum density of such disturbances. The two EM fields are found as the formal features of the potentials. Moreover, the charge and current, as the apparent carriers, are reduced to formal features of the fields. By the way, the three relevant algebraic relations are confirmed in return.

Concerning moving line conductors, with their electricity and currents, the algebraic relations phenomenally show their kinetic senses. With respect to accelerated electricity in a conductor, the known – so-called *static* – induction reveals its dynamic essence. The process of the polarization of the medium around a moving charged particle thus causes the dynamic force component – in the kinetic central law. In the opposite sense, the centrifugal force, in the dynamic law, is here interpreted as the kinetic effect of magnetic quantities. Though the static and dynamic components of electric fields are initially distinguished, there appears their essential unity in 4D space. Electric kinetic quantities represent the formal substitutes of the magnetic force action.

By the fillings in of the inherited gaps, EM theory is here completed and, as such, affirmed in the crucial applications. Apart from the central laws, the elementary applications of the algebraic equations are demonstrated in the last four sections. Unknown or neglected in the standard presentations, they are here emphasized as the alternative approach to the fundamentals of EM theory, convenient at consideration of moving bodies. Not only that this approach confirms all the known classical results, but essentially contributes to their formal completion and rational interpretations. With better understanding of EM waves and their propagation, moving media are here treated and interpreted. Poynting's theorem is finally identified as a 5D continuity equation, announcing a structural dimension, as the fifth axis.

16. Conclusions

1. Algebraic relations are here reaffirmed, re-examined and successfully applied. 2. By help of the field motion, the general kinetic law is formulated. 3. The central laws firmly mutually relate some, as if so far fully independent, results: Coulomb's law, Einstein's equation, classical radius & EM mass, EM induction, force action law, inertial & centrifugal forces, mass function, mass defect, associated waves and ellipsoidal field deformations. 4. The standard differential equations are obtained in the axiomatic order, starting from the static potential. 5. The three basic sets supplement each other in the interpretations and applications. 6. A number of the classical experimental results is consistently explained. 7. The principle of relativity and assumption of elementary mass are convincingly called in question.

REFERENCES

[1] H. A. Lorentz, A. Einstein, H. Minkowski, The principle of relativity, New York, 1923.

[2] N. Macleod, Faraday's disk revisited: some new experiments concerning unipolar EM induction, Physics Essays, December 2012, Vol. 25, No. 4, pp 524-531.

[3] H. A. Lorentz, The Theory of Electrons, Columbia University Press, New York 1909.

[4] A. Arbab, The analogy between electromagnetism and hydrodynamics, Physics Essays, June 2011, Vol. 24, No. 2, pp 254-259.

[5] B. Mišković, Essential Overview of EM Theory, Springer-Verlag, Selected Topics in Nonlinear Dynamics and TEE, Volume 459, 2013, pp 234-254, Chapter 13.

[6] B. Mišković, Inductive Elaboration of EM Theory, Scientific & Academic Publishing – International Journal of Electromagnetics and Applications, Vol.3, No. 3, 2013.

[7] B. Mišković, Deductive Exposition of EM Theory, Scientific & Academic Publishing, International Journal of Electromagnetics and Applications, Vol. 3, No. 2, 2013.

[8] B. Mišković, Thematic Consideration of EM Theory, SAP, International Journal of Theoretical and Mathematical Physics, Vol. 3, No. 4, 2013.

[9] B. Mišković, Boundary Questions of EM Theory, SAP, International Journal of Theoretical and Mathematical Physics, Vol. 4, No. 3, 2014.

[10] B. Mišković, ELECTRODYNAMICS (in Serbo-Croatian), http://solair.eunet.rs/~brami/.

[11] B. Mišković, GENERAL PHYSICS (in Serbo-Croatian), http://solair.eunet.rs/~brami/.