Inductive Elaboration of EM Theory

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***Abstract*—With some its additional elaboration, an original development of EM theory is here presented, from the cruder to the finer levels of observation. Dual conception of the two EM fields is gradually transferred into trilateral system of radial – static, transverse – kinetic and longitudinal – dynamic elementary forces, in the functions of position, motion and acceleration of interacting charges. Three sets of the basic equations, relating the three ranks of EM quantities, are presented. Their senses and ranges of validity are determined.**

Keywords—EM theory (EMT); basic laws; central fields; algebraic relations; differential equations

I. Algebraic Relations

At motion of their carriers, moving associated fields are producing the *dissimilar* EM fields. Thus obtained fields interact with *similar* present fields, as if the present fields react directly onto *moving dissimilar* objects, by respective *equivalent fields*. These two processes are described by the *convective* (6) and *relative* (7) algebraic pairs:

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

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

$$\mathbf{E}_{ef} = (\mathbf{v}-\mathbf{U})\times\mathbf{B}, \qquad \mathbf{H}_{ef} = (\mathbf{V}-\mathbf{u})\times\mathbf{D}. \tag{8}$$

Here $\mathbf{V}$ is the speed of electric, and $\mathbf{U}$ – of magnetic fields, and $\mathbf{v}$ & $\mathbf{u}$ – of respective objects. Irrespective of the force nature, nominally similar fields from (6) & (7) formally add, giving the summary *effective* interactions (8).

The validities of the algebraic relations are somehow restricted. Due to cross-products, the motion *transverse* to the field lines is understood. Moreover, *the field motion is effective only along its own gradient.* Unlike a *non-vortical* (electric) moving field – (6a), generally inhomogeneous in any direction, the gradient of a *vortical* (magnetic) field – (6b), is restricted to the planes of its field lines.

In this sense, *radial* motion of a conductor with its field, gives the *axial* induction (6b). The moving gradient changes the field in the observed location, with respective reaction of the medium. Similar effect arises around a variable line current, as the accelerated electricity, producing respective circular magnetic field, expanding or shrinking radially. Radial motion causes *reactive* axial induction, in all parallel conductors, including the carrying conductor itself.

On the other hand, the object speed in (7a) is effective in both transverse directions: *axial* motion causes *radial* induction, and opposite. By respective forces, parallel currents attract, and opposite ones repel each other, and so crosswise conductors tend to the same courses of their currents. And in common, a free moving charge is compelled to circular motion around lines of the present magnetic field.

The *axial* motion is tested by the two Faraday's experiments. An instrument is connected by sliding contacts between the center and rim of a conducting disc, rotating in the front of a cylindrical magnet, around the common axis. The magnetization current (on the magnet cover) interacts with free electricity (of disc) moving in parallel. This interaction of the two circular currents looks as respective radial induction in the disc, or the equivalent field (7a).

Irrespective of (6b), the same rotation of the magnet does not produce any inductive effect. The same former signal arises at reconnection of the contacts to the rotating magnet itself. The magnet body now takes over the role of the disc, with the same magnetic interaction.

II. Central Laws

Elementary EM interactions are caused by the *presence*, *motion* and *acceleration* of punctual charges. A charge affects another one by the *static central force*:

$$f_s = n/\varepsilon\mu = nc^2, \qquad n = \mu q_1 q_2/4\pi r_{1,2}^2 = \varepsilon\mu q_2 E_s; \tag{9}$$

$$w = m/\varepsilon\mu = mc^2, \qquad m_o = \mu q^2/4\pi r_o. \tag{10}$$

Radial integration gives respective potential energy, with the factor $m = nr$, as the *mutual* and *proper* masses. These two masses represent elementary factors of *induction* and *self-induction*, respectively. As the condition of the two laws equivalence, the relation (10b) was the basis for the direct calculation of the 'classical' electron radius.

Two moving charges interact by additional EM forces. The field (6a) substituted into (8a) would give the general kinetic interaction. In this aim, let us determine the magnetic field motion around a moving charge. The central potential, 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:

$$U = \frac{\partial y}{\partial t} = -\frac{\partial y}{\partial x}\frac{\partial x}{\partial t} = -V\frac{\partial y}{\partial x} = V\frac{x}{y} = V\cot\theta. \tag{11}$$

In accord to (19a & 18b), transverse gradient of the moving potential is nothing else than magnetic field. The field lines expand in front, and shrink behind a moving charge, thus producing the longitudinal force component (12).

Due to simplicity, let us restrict to the parallel motion. (Some transverse object speed would produce the additional longitudinal force component.) In this case, (6a, 8a & 11) give transverse *magnetic*, and longitudinal *electric* forces, of the *kinetic* and *dynamic* fields, respectively:

$$\mathbf{f}_{1,2} = q(\mathbf{E}_k + \mathbf{E}_d) = -nV(v\sin\theta\,\mathbf{i}_t + V\cos\theta\,\mathbf{i}_l); \tag{12}$$

$$w_{1,2} = -mV(v\sin^2\theta + V\cos^2\theta)\,. \qquad (13)$$

Radial integration of the forces gives *mutual kinetic* energy. The kinetic field is in fact the magnetic interaction of two moving charges, as the parallel currents.

The longitudinal (dynamic) component, directed towards the moving charge, does not depend on the object motion (v). Acting to all the present electric charges, it looks as an associated wave period. Subtracted from the central static field – extracted from (9), it causes the ellipsoidal field deformation, somehow predicted by H. Lorentz.

In the case of the equal speeds of the field carrier and its object, the full force (12) and energy (13) are reduced into the central forms. The comparison with (9) & (10) identifies the static laws as the opposite special cases of these ones, at the speed c – of all the particles. This analogy points to the common motion along the temporal axis, related with cosmic expansion. The negative sign announces some motion in **r***t*-planes, superimposed to the expansion.

Affecting in return the carrier itself, the obtained central force is distributed about the particle surface, and thus subtracted from respective static force (9):

$$f = n(\mathrm{c}^2 - v^2) = n\mathrm{c}^2(1 - v^2/\mathrm{c}^2) = n\mathrm{c}^2 g^2\,. \qquad (14)$$

With the particle model – as the *elastic sphere*, this force should be opposed by some external pressure, independent of the speed: $f_o = n_o\mathrm{c}^2$, where $n_o = n(r_o)$. Keeping the equilibrium with the decreasing force (14), the external pressure compresses the radius ($r = gr_o$) and thus increases the particle mass (10b) – in the ratio: $m = m_o/g$.

The obtained *mass-function* speaks in favor of the *inertia* and *induction* equivalence. With respect to the *mass differential*, $\partial m = mv\partial v/(\mathrm{c}^2 - v^2)$, there follows the *proper kinetic* energy of a moving (charged) particle:

$$\partial w_k = p\partial t = vf\partial t = v\partial(mv) = mv\partial v + v^2\partial m = \mathrm{c}^2\partial m\,, \qquad (15a)$$

$$w_k = w - w_o = (m - m_o)\mathrm{c}^2 = q^2(1/r - 1/r_o)/4\pi\varepsilon\,. \qquad (15b)$$

The term $mv\partial v$ accords to classical kinetic energy, assuming the constant mass. The last equality relates the proper kinetic energy with that of EM fields between the two radii. This is well-known Einstein's result, obtained accidentally, without the mentioned EM interpretation.

Unlike the dynamic force component – at *uniform motion* (12), the relation (10b) of mass and charge also points to some dynamic forces at *accelerated motion*, expressed by the known *force action law*. Of course, apart from the body *acceleration*, the dynamic force also depends on its *speed*, via the *variable mass* or the factor g:

$$\mathbf{f}_d = -\frac{\partial(mv\mathbf{v}_o)}{\partial t} = \frac{mv^2}{r}\mathbf{r}_o - \frac{m}{g^2}\frac{\partial v}{\partial t}\mathbf{v}_o\,. \qquad (16)$$

There are the two forces, *centrifugal* and *inertial*. Instead of respective two different masses, they are the distinct functions of the same variable mass. The former force strives to the strait direction, and the latter opposes linear acceleration, with respective transfer of energy. The comparison with the two components of (12) points that the former force may be of magnetic, and latter – of electric natures.

III. Differential Equations

Some generalization of the central fields, and their comparison with the two potentials, gives the three pairs of differential equations, *static*, *kinetic* and *dynamic*:

$$\nabla\bullet\mathbf{D} = Q\,, \qquad \nabla\times\mathbf{H} = \mathbf{J}_{tot}\,, \qquad \nabla\times\mathbf{E} = -\partial_t\mathbf{B}\,; \qquad (17)$$

$$\mathbf{E}_s = -\nabla\Phi\,, \qquad \mathbf{B} = \nabla\times\mathbf{A}\,, \qquad \mathbf{E}_d = -\partial_t\mathbf{A}\,; \qquad (18)$$

$$\mathbf{A} = \varepsilon\mu\Phi\mathbf{V}\,, \qquad \nabla\bullet\mathbf{A} = -\varepsilon\mu\,\partial_t\Phi\,. \qquad (19)$$

The set (17) is known as *Maxwell's equations*, and (18) – as *gauge conditions*. The mutual comparison of the potentials relates them algebraically and differentially (19). The latter of them only was used so far. These two equations point to the fluidic interpretation of EM phenomena.

In this sense, starting from a hypothetical, *compressible*, *super-fluidic* and *inert* medium, EM potentials can be introduced as the fluidic states of this medium. If the static potential (Φ) be understood as the pressure disturbance of the fluid, its motion will give the kinetic potential (19a), as the *massive fluid flow* or *linear momentum density*. The two EM constants, as the factors of *compressibility* (elasticity) or the *regular mass density* of the fluid, finally give its linear momentum density. As such, these two constants determine the speed of EM wave propagation: $\mathrm{c}^2 = 1/\varepsilon\mu$.

On these fundamental bases, the gauge conditions can be logically introduced. The static condition (18a) points to the pressure disturbances, as the static field causes. Tending to the fluid homogeneity, two equipolar disturbances repel, and opposite ones attract each other. The fluid flows are affected by kinetic forces, attracting parallel, and repelling opposite currents, as the collinear vectors. These forces are expressed by the circular *magnetic field*, as the transverse gradient of the fluid flow (18b). The dynamic condition (18c) is nothing else than *force action law* (16), here applied to the linear momentum density. In fact, *the three EM fields are only the differential features of the two potentials*.

On the other hand, in analogy to *electric* displacement current – in (17b), time derivative of the magnetic field – in (17c), at least formally, may be considered as the *magnetic* displacement current. In this sense, the three relevant Maxwell's equations (17) define the *carriers* (charge and currents) as the *formal features of the fields*. The fields are the derivatives of potentials, and carriers – of the fields. Therefore, the carriers are the second order derivatives of the potentials. Between the three types of physical quantities, the two potentials, as some density disturbance and its motion, appear as the fundamental EM quantities.

IV. Conclusion

Three stages of EM theory are presented. *Algebraic relations* kinetically link the two fields & their moving objects, and *central laws* determine EM forces acting on the *present*, *moving* and *accelerated* charges. The three fields represent the *static*, *kinetic* and *dynamic* effects, described by respective differential equations. Mechanical inertia is convincingly explained by EM induction.

Reference

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