Journal of High Energy Physics, Gravitation and Cosmology, 2026, 12(1), 76-106
https://www.scirp.org/journal/jhepgc
ISSN Online: 2380-4335
ISSN Print: 2380-4327

Electromagnetic Fields and Interactions Explained by the Theory of Informatons

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How to cite this paper: Acke, A. (2026) Electromagnetic Fields and Interactions Explained by the Theory of Informatons. *Journal of High Energy Physics, Gravitation and Cosmology*, **12**, 76-106.
https://doi.org/10.4236/jhepgc.2026.121005

Received: December 15, 2025
Accepted: December 28, 2025
Published: December 31, 2025

Abstract

This article is about the electromagnetic interactions and the physical nature of the medium that mediates in these interactions. We propose a model in which that medium—the "electromagnetic field" or "EM field"—is a substantial element of nature. It will be shown that an EM field can be identified as an expanding cloud of informatons that mathematically is characterized by the dual vector field ($\boldsymbol{E}, \boldsymbol{B}$). We start from the idea that each material object manifests itself in space by continuously emitting—at a rate proportional to its rest mass—massless and energy less granular entities carrying data that, besides referring to the position and the mass of its emitter, refer to its electric charge and to its velocity. Because they transport nothing else than information, we call these entities that—relative to an inertial reference frame—are rushing away with the speed of light "informatons". The idea that an EM field is an expanding cloud of informatons emitted by an electrically charged object leads, in particular, to the insight that the electric field vector $\boldsymbol{E}$ and the magnetic field vector $\boldsymbol{B}$ respectively characterize the density of the flow of electric information and the density of the cloud of magnetic information at an arbitrary point in an EM field. And that the electromagnetic interactions can be explained as the reaction of a (moving) point charge on the disturbance of its proper EM field by the EM field that in its direct vicinity is created and maintained by other field sources.

Keywords

Electromagnetism, Informatons, Coulomb's Law, Biot-Savart's Law, Ampère's Law, Lorentz Force

1. Introduction

In the context of classical electrodynamics, the *Lorentz force law* describes the electromagnetic interactions, *i.e.* the interactions between electric charges and currents separated in space. A dual vector field ($\boldsymbol{E},\boldsymbol{B}$), called the "*electromagnetic field*" (in short the "*EM* field"), has been introduced as the entity that mediates in these interactions. A set of four coupled partial differential equations ("*Maxwell's equations*" or "*Maxwell-Heaviside equations*") describes how an EM field is generated and how spatial changes of $\boldsymbol{E}$ are related to temporal fluctuations of $\boldsymbol{B}$ and vice versa.

Although classical electrodynamics describes the electromagnetic phenomena and laws in a correct and coherent manner, it does not create clarity about the physical nature of the EM field: the EM field is considered as a purely mathematical construction.

In this article the idea is developed that, if electrically charged objects can influence each other "at a distance", they must in one way or another exchange data. We start from the idea that an electrically charged material object manifests itself in space by the emission—at a rate proportional to its rest mass—of mass and energy less granular entities that are rushing away with the speed of light and that, besides data referring to the mass and the position of their emitter ("*gravitational information*"), are carrying data regarding its electric charge ("*electrical information*") and regarding its velocity ("*gravitomagnetic* and *magnetic* information"). Because they transport nothing else than information, we call these entities "*informatons*". In this way we propose a physical foundation of classical electrodynamics by introducing *information as the substance of EM fields*.

The electromagnetic field of an electrically charged object will be understood as an expanding cloud of informatons that forms an indivisible whole with that object. At an arbitrary point *P*, it is characterized by *the density of the flow of electric information* and the *density of the cloud of magnetic information*. These vectoral quantities can be identified with $\boldsymbol{E}$ and with $\boldsymbol{B}$, respectively the electric field vector and the magnetic field vector that in the context of classical electrodynamics mediate in the electromagnetic interactions.

Finally we explain the electromagnetic interaction between electrically charged particles and electric currents as the reaction of an electrically charged object to the disturbance of its "proper" EM field by the EM field that, in its direct vicinity, is created and maintained by other field sources.

2. Preliminary Definitions

A material object occupies space, its surface encloses matter. The amount of matter within its contours is called its *mass*. According to the field theory, any material object generates a gravitational field. At a sufficiently large distance this field is independent of the shape of the object. This "far gravitational field" can be calculated by reducing its source to a "mathematical point" in which all the mass of the object is accumulated. Such a material point is called a "*particle*". A material object that contains *electrically charged matter* generates in addition an electric field. The "far electric field" of that object is completely defined by the electrically charged matter (in short *the electric charge*) accumulated in the particle that represents the object.

If we focus on the mass of the object that it represents, a particle is called a "*point mass*" and if we focus on its electric charge it is called a "*point charge*". In the first case we represent the particle as a little sphere and in the second case as a little sphere that—depending on the case—includes a plus- or a minus sign.

If we can calculate the gravitational field (the electric field) generated by a point mass (a point charge), integral calculus delivers the method to calculate the gravitational field (the electric field) generated by any material body.

The phenomena that are the subject of this article are situated in spacetime: they are located in "space" and dated in "time".

1) In this context *space* is conceived as a three-dimensional, homogeneous, isotropic, unlimited and empty continuum. This continuum is called the "Euclidean space" because that what there geometrically is possible is determined by the Euclidean geometry. By anchoring a standardized Cartesian coordinate system to a reference body, an observer can—relative to that reference body—localize each point by three coordinates x, y, z.

2) In the same context we define *time* as the monotonically increasing real quantity t that is generated by a standard clock[1]. In a Cartesian coordinate system a standard clock links to each event a "moment"—this is a specific value of t and to each duration a "period" or "time interval"—this is a specific increase of t. The introduction of time makes it possible for the observer to express, in an objective manner, the chronological order of events in a Cartesian coordinate system.

A Cartesian coordinate system together with a standard clock is called a "*reference frame*". We represent a reference frame as $OXYZ(T)$, shortly as $\boldsymbol{O}$. A reference frame is called an "*inertial reference frame*" (an "*IRF*") if light propagates rectilinear (in the sense of the Euclidean geometry) with constant speed everywhere in the empty space linked to that frame. This definition implies that the space linked to an IRF is a homogeneous, isotropic, unlimited and empty continuum in which the Euclidean geometry is valid.

3. The postulate of the Emission of Informatons

3.1. The Concept of Gravitational or G-Information

Newton's law of universal gravitation [1] may be expressed as follows: *The gravitational force* $\boldsymbol{F}$ *between any two particles having masses* m_1 *and* m_2 *separated by a distance r is an attraction working along the line joining the particles and has a magnitude*

$$F = G \cdot \frac{m_1 \cdot m_2}{r^2}$$

where $G = 6.6732 \times 10^{-11}\, \mathrm{N \cdot m^2/kg^2}$ *is a universal constant having the same value for all pairs of particles.*

[1]The operation of a standard clock is based on the counting of the successive cycles of a periodic process that is generated by a device inside the clock.

This law expresses the basic fact of gravitation, namely that two masses are interacting "at-a-distance": they exert forces on one another even though they are not in contact.

According to Newton's law $\boldsymbol{F}_B$, the force exerted by a particle *A*—with mass m_1—on a particle *B*—with mass *m*—is pointing to the position of *A* and has a magnitude:

$$F_B = \left(G \cdot \frac{m_1}{r^2} \right) \cdot m$$

The orientation of this force and the fact that it is directly proportional to the mass of *A* and depends on the position of that particle relative to *B* implies that particle *B* must receive *information* about the presence in space of particle *A*: particle *A* must send *data* to *B* about its position and about its mass. This conclusion is independent of the position and the mass of *B*. So, we can generalize it and posit that: *Any particle manifests itself in space by emitting information about its mass and about its position*. We consider that type of information as a substantial element of nature and call it "*gravitational information*" or "*g-information*".

3.2. The Concept of Electrical or E-Information

Two point charges at rest in vacuum exert relative to an IRF an electric force $\boldsymbol{F}$ on one another. Between charges of like sign this force is repulsive and between charges of unlike sign it is attractive. The precise value of the electric force that one charged particle exerts on another is given by Coulomb's law [2]:

The magnitude of the electric force $\boldsymbol{F}$ *that a particle with charge* q_1 *exerts on another particle with charge* q_2 *is directly proportional to the product of their charges and inversely proportional to the square of the distance r between them. The direction of the force is along the line joining the particles.*

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{|q_1| \cdot |q_2|}{r^2}$$

where $\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F/m}$ *is the permittivity constant.*

Coulomb's law expresses the basic fact of electrostatics, namely that two point charges are interacting "at-a-distance". According to this law $\boldsymbol{F}_B$, the electric force exerted by a point charge *A* with charge q_1 on a point charge *B* with charge *q* is pointing to the position of *A* if the signs of the charges are unlike and in the opposite direction if they are like. The magnitude of that force is:

$$F_B = \left(\frac{1}{4\pi\varepsilon_0} \cdot \frac{|q_1|}{r^2} \right) \cdot |q|$$

The fact that the orientation of $\boldsymbol{F}_B$ depends on the sign and on the position of particle *A* relative to *B*, and that its magnitude is determined by the magnitude of the charge of *A* and by the distance between *B* and *A* implies that particle *B* must receive *information* from particle *A*. More specifically particle *B* must receive *data* referring to the position of particle *A* and to the magnitude and the sign of its electric charge. *This means that particle A must manifest its presence in space by sending data about the magnitude and the sign of its charge and about its position*. We consider this type of information just like g-information as a substantial element of nature and call it "*electrical information*" or "*e-information*".

3.3. The Postulate of the Emission of Informatons

We assume that a particle manifests its presence in space by continuously emitting granular carriers of g- and, if it is electrically charged, of e-information. These information carriers are called "informatons". The emission of informatons by a particle anchored in an IRF ***O***, is governed by the "*postulate of the emission of informatons*".

A. *The emission* of informatons by a particle at rest is governed by the following rules:

1) *The emission is uniform in all directions of space, and the informatons diverge with the speed of light* ($c = 3 \times 10^8$ *m/s*) *along radial trajectories relative to the position of the emitter*.

2) $\dot{N} = \frac{\mathrm{d}N}{\mathrm{d}t}$, *the rate at which a particle emits informatons*[2], *is time independent and proportional to the rest mass* m_0 *of that particle. So, there is a constant K so that*:

$$\dot{N} = K \cdot m_0$$

3) *The constant K is equal to the ratio of the square of the speed of light* (c) *to the Planck constant* (h):

$$K = \frac{c^2}{h} = 1.36 \times 10^{50}\ \mathrm{kg}^{-1} \cdot \mathrm{s}^{-1}$$

B. We call the essential attribute of an informaton its *g-index*. The g-index of an informaton refers to information about the position of its emitter and equals the *elementary quantum of g-information*. It is represented by a vectoral quantity $\boldsymbol{s}_g$:

1) $\boldsymbol{s}_g$ *points to the position of the emitter*.

2) *The elementary quantum of g-information is*:

$$s_g = \frac{1}{K \cdot \eta_0} = \frac{h}{\eta_0 \cdot c^2} = 6.18 \times 10^{-60}\ \mathrm{m}^3 \cdot \mathrm{s}^{-1}$$

where $\eta_0 = \frac{1}{4 \cdot \pi \cdot G} = 1.19 \times 10^9\ \mathrm{kg} \cdot \mathrm{s}^2 \cdot \mathrm{m}^{-3}$, G being the gravitational constant.

C. Informatons emitted by an electrically charged particle at rest in an IRF, carry in addition an attribute that refers to the *electric charge per unit mass* of their emitter, namely the *e-index*. e-indices are represented as $\boldsymbol{s}_e$ and defined by:

1) *The e-indices are radial relative to the position of the emitter. They are cen-*

[2]We neglect the possible stochastic nature of the emission. It is responsible for noise on the quantities that characterize the electric field. So, $\dot{N}$ is the average emission rate.

trifugal when the emitter carries a positive charge ($q=+Q$) *and centripetal when the charge of the emitter is negative* ($q=-Q$).

2) s_e, *the magnitude of an e-index depends on* Q/m_0, *the charge per unit of rest mass*[3] *of the emitter. It is defined by*:

$$s_e=\frac{1}{K\cdot\varepsilon_0}\cdot\frac{Q}{m_0}=8.32\times10^{-40}\cdot\frac{Q}{m_0}\text{kg}\cdot\text{m}^3\cdot\text{s}^{-1}\cdot\text{C}^{-1}$$

where $\varepsilon_0=8.85\times10^{-12}\ \text{F/m}$ *is the permittivity constant.*

Rule A.1 is the expression of the hypothesis that the space is a homogenous and isotropic continuum in which the gravitational and electromagnetic phenomena are travelling with the speed of light. Rule A.2 posits that the rate at which a particle emits informatons is a measure for its rest mass and rule A.3 implies the fact that, when a particle absorbs (emits) a photon $h\cdot\nu$, its rest mass is increasing (decreasing) with an amount $\frac{h\cdot\nu}{c^2}$ while its emission rate is increasing (decreasing) with an amount ν.

Rule B.1 and rule B.2 identify informatons as the constituent elements of gravitational fields and g-information as the substance of these fields.

Rule C.1 and rule C.2 identify informatons emitted by an electrically charged particles as the constituent elements of electric fields and e-informatons as the substance of these fields.

To summarize, *each material object manifests itself in space by the emission of informatons. Informatons are carriers of the elementary quantum of g-information and as such the constituent elements of gravitational fields. If their emitter is electrically charged, they are also carriers of the elementary quantity of e-information and they are as such the constituent elements of electric fields.*

4. The Electric Field

4.1. The Emission of Informatons by a Particle at Rest

In **Figure 1**, we consider an electrically charged particle with rest mass m_0 and electric charge q that is anchored at the origin of an IRF ***O***. The particle is the source of both g- and e-information.

From art. A of the postulate of the emission on informatons it follows that that particle is the source and the center of a—with the speed of light—expanding spherical cloud of informatons. It is evident that the rate at which that particle emits informatons is also the rate at which it sends informatons through any closed surface surrounding it. So, the postulate of the emission of informatons implies that the *intensity of the flow of informatons* through any closed surface that encloses the particle is:

$$\dot{N}=\frac{\text{d}N}{\text{d}t}=K\cdot m_0$$

If the closed surface is a sphere with radius *r*, the *intensity of the flow of in-*

[3]From the definition of a particle as a *material point*, it follows that *q*, the electric charge of an electrically charged particle, is evenly distributed over m_0, its rest mass.

formatons per unit area is given by:

$$\frac{K \cdot m_0}{4 \cdot \pi \cdot r^2} \tag{1}$$

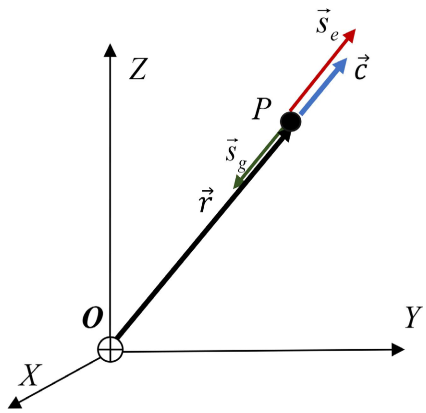

Figure 1. The emission of an informaton by an electrically charged particle.

This is at any point *P* at a distance *r* from their source the "*density of the flow of informatons*", *i.e. the rate per unit area at which these informatons cross an elementary surface perpendicular to the direction in which they move*.

For each spatial region in the wide area of the particle the inflow of informatons equals the outflow. That is why each spatial region contains an unchanging number of informatons and thus a constant quantity of g- and e-information. Moreover, the orientation of the g- and e-indices of the informatons passing near an arbitrary point is time-independent. And in addition, each spatial region contains a very large number of informatons which makes that the cloud of informatons can be considered as a continuum. If we focus on the g-information as its substance, that continuum is called the "*gravitational field*" or the "*g-field*" of the particle and if we focus on the e-information it is referred to as its "*electric field*" or its "*e-field*".

The present paper is about the electromagnetic field and about the electromagnetic phenomena: the particle is considered as a *point charge*. In our publications [3]-[6] the gravitational field and the gravitational phenomena were discussed in detail. In that context the particle is considered as a point mass.

4.2. The Electric Field or the E-Field of a Point Charge at Rest

Focusing on the particle as a *point charge q*, the informatons in **Figure 1** with velocity

$$\boldsymbol{c} = c \cdot \frac{\boldsymbol{r}}{r} = c \cdot \boldsymbol{e}_r$$

pass near point *P*—defined by the position vector $\boldsymbol{r}$ —are, according to art. C of the postulate of the emission of informatons, characterized by their e-index $\boldsymbol{s}_e$:

$$s_e = \frac{q}{m_0} \cdot \frac{1}{K \cdot \varepsilon_0} \cdot \frac{\boldsymbol{r}}{r} = \frac{q}{m_0} \cdot \frac{1}{K \cdot \varepsilon_0} \cdot \boldsymbol{e}_r \tag{2}$$

The density (*i.e.* the rate per unit area perpendicular to c) of the flow of e-information at P is the product of the density of the flow of informatons with s_e, the elementary e-information quantity. So, combining (1) and (2) we become the following expression for the density of the flow of e-information at P:

$$\frac{K \cdot m_0}{4 \cdot \pi \cdot r^2} \cdot \frac{q}{m_0} \cdot \frac{1}{K \cdot \varepsilon_0} = \frac{q}{4 \cdot \pi \cdot \varepsilon_0 \cdot r^2}$$

This quantity is, together with the orientation of the e-indices of the informatons that are passing near P, characteristic for the electric field at that point. Thus, at a point P, the electric field of a point charge q is unambiguously characterized by the vectoral quantity $\boldsymbol{E}$ defined as:

$$\boldsymbol{E} = \frac{\dot{N}}{4 \cdot \pi \cdot r^2} \cdot \boldsymbol{s}_e = \frac{q}{4 \cdot \pi \cdot \varepsilon_0 \cdot r^2} \cdot \boldsymbol{e}_r = \frac{q}{4 \cdot \pi \cdot \varepsilon_0 \cdot r^3} \cdot \boldsymbol{r}$$

At an arbitrary point, this quantity—called the *electric field vector*—characterizes the *electric field* or shortly the "*e-field*" of q.

We conclude: *At any point P of the electric field generated by a point charge at rest relative to the IRF* ***O****, E—the magnitude of* $\boldsymbol{E}$ *—characterizes the density of the flow of e-information* (*i.e. the rate per unit area at which e-information crosses an elementary surface perpendicular to the direction in which the informatons move*). *And* $\boldsymbol{E}$ *is pointing to the position of the source of the field if particle q is electrically negative and in the opposite direction if q is positive.*

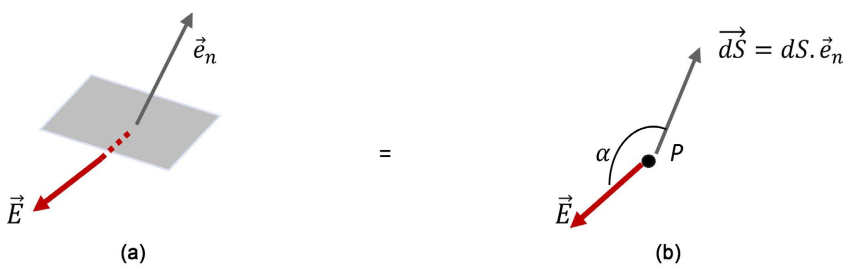

Figure 2. The flux through a surface element.

In Figure 2(a) we consider a surface-element dS at P. Its orientation and its magnitude are completely determined by the surface-vector d$\boldsymbol{S}$ (Figure 2(b)). By $\mathrm{d}\Phi_E$, we represent the rate at which e-information flows through dS in the sense of the positive normal $\boldsymbol{e}_n$ and we call the scalar quantity $\mathrm{d}\Phi_E$, defined as

$$\mathrm{d}\Phi_E = \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{S} = E \cdot \mathrm{d}S \cdot \cos\alpha$$

the *elementary e-flux through* dS.

4.3. The Electric Field of a Set of Point Charges at Rest

We consider a set of charged particles with electric charges $q_1, \cdots, q_i, \cdots, q_n$ that are anchored in an IRF $\boldsymbol{O}$. At an arbitrary point P, the flows of e-information that are emitted by the distinct particles are defined by the electric field vectors $\boldsymbol{E}_1,\cdots,\boldsymbol{E}_i,\cdots,\boldsymbol{E}_n$.

$\mathrm{d}\Phi_E$, the rate at which e-information flows through a surface-element $\mathrm{d}S$ at P in the sense of the positive normal, is the sum of the contributions of the distinct charges:

$$\mathrm{d}\Phi_E = \sum_{i=1}^{n}\left(\boldsymbol{E}_i \cdot \mathrm{d}\boldsymbol{S}\right) = \left(\sum_{i=1}^{n}\boldsymbol{E}_i\right)\cdot \mathrm{d}\boldsymbol{S} = \boldsymbol{E}\cdot \mathrm{d}\boldsymbol{S}$$

So, the *effective density of the flow of e-information at P* (the effective electric field vector) is completely defined by:

$$\boldsymbol{E} = \sum_{i=1}^{n}\boldsymbol{E}_i$$

We conclude: *At a point in space, the electric field of a set of point charges at rest is completely defined by the vectoral sum of the electric field vectors characterizing the electric fields of the distinct particles.*

4.4. The Electric Field of a Charge Continuum at Rest

We call an object in which the electric charge is spread over the occupied volume in a time independent manner, a *charge continuum*.

At each point M in such a continuum, the accumulation of charge is characterized by the charge *density* ρ_E. To define this scalar quantity, one considers the charge $\mathrm{d}q$ in a volume element $\mathrm{d}V$ that contains M. The accumulation of charge in the vicinity of M is defined by the charge density ρ_E:

$$\rho_E = \frac{\mathrm{d}q}{\mathrm{d}V}$$

A charge continuum—anchored in an IRF—is equivalent to a set of infinitely many infinitesimal small charge elements $\mathrm{d}q$. The contribution of each of them to the e-field at an arbitrary point P is characterized by $\mathrm{d}\boldsymbol{E}$. $\boldsymbol{E}$ —the effective electrical field vector at P—is the result of the integration over the volume of the continuum of all these contributions.

4.5. The Law of Conservation of Electric Information

It is evident that $\Phi_E = \oiint \boldsymbol{E}\cdot \mathrm{d}\boldsymbol{S}$ —*the rate at which e-information flows out of an arbitrary closed surface S—must equal the rate at which e-information is generated by the enclosed electric charge*. This is the "law of conservation of e-information".

1) In the case where the enclosed charge is a point charge q, the rate at which e-information is generated is $\dot{N}\cdot s_e = \frac{q}{\varepsilon_0}$. We conclude:

$$\oiint \boldsymbol{E}\cdot \mathrm{d}\boldsymbol{S} = \frac{q}{\varepsilon_0}$$

2) In the case where the enclosed charge $q_{in} = \sum_1^n q_i$ is a set of point charges, it is easy to show that:

$$\Phi_E = \oiint \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{S} = \frac{q_{in}}{\varepsilon_0}$$

3) And in the case where the enclosed charge is a charge continuum:

$$\oiint_S \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{S} = \frac{1}{\varepsilon_0} \cdot \iiint_V \rho_E \cdot \mathrm{d}V$$

These different expressions of the law of conservation of e-information are mathematical expressions of *Gauss's law*.

According to the theorem of Ostrogradsky [7], the last relation is equivalent to:

$$div\boldsymbol{E} = \frac{\rho_E}{\varepsilon_0}$$

4.6. The Electric Field of a Charge (-Distribution) at Rest Is Conservative

It's easily shown that the *electrostatic* field, *i.e.* the electric field of a charge (-distribution) at rest is conservative [2]. This means that the line integral of $\boldsymbol{E}$ is path-independent, what implies [7]

1) *For any closed path in an electrostatic field it applies*:

$$\oint \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{l} = 0 \quad \text{or} \quad rot\boldsymbol{E} = 0$$

2) *The electrostatic field can be derived from a potential function V*:

$$\boldsymbol{E} = -gradV$$

5. The Electrostatic Interaction between Point Charges at Rest—Coulomb's Law

5.1. The Electric Force on a Point Charge in an Electric Field

We consider a set of electrically charged particles anchored in an IRF $\boldsymbol{O}$. They create and maintain—besides a gravitational field—an electric field that at each point of the space linked to $\boldsymbol{O}$ is completely determined by the vector $\boldsymbol{E}$. Each particle is "immersed" in a cloud of e-information. At every point, except at its own position, each particle contributes to the construction of that cloud.

Let us focus on the particle with mass m_0 and charge q anchored at P. If the other particles were not there, then that particle would be at the center of a perfectly spherical cloud of e-information (the particle's "*electric self-field*"). In reality this is not the case: the emission of e-information by the other point charges is responsible for the disturbance of the "*characteristic symmetry*" of the e-field in the vicinity of P. Because $\boldsymbol{E}$ at P is the density of the flow of e-information send to that point by the other charges, it is a measure for the extent to which the characteristic symmetry of the point charge q is disturbed.

We assume that, *when a charged particle can freely move*, *it reacts to the disturbance by an external electric field by accelerating so that the field's influence on its motion is fully expressed in its acceleration*. In its proper IRF, the particle perceives only its own spherically symmetric electric self-field and becomes "blind" to the external field.

This reaction implies that a point charge q at a point P in an electric field $\boldsymbol{E}$ experiences an action because of that field; if it is anchored that action is compensated by the anchorage.

1) That action is proportional to the extent to which the characteristic symmetry of the electric field in the vicinity of q is disturbed by the extern e-field, thus to $\boldsymbol{E}$ at P.

2) It depends also on the magnitude of q. Indeed, the e-information cloud created and maintained by q is more compact as q is greater. That implies that the disturbing effect on the characteristic symmetry of the electric field in the direct vicinity of q by the extern e-field $\boldsymbol{E}$ is smaller when q is greater. Thus, to impose a certain acceleration, the action of the electric field on q must be greater as q is greater.

We can conclude that the action that tends to accelerate a particle anchored in an electric field must be proportional to $\boldsymbol{E}$, the e-field to which the particle is exposed, and to q, the charge of the particle. We represent that action by $\boldsymbol{F}_E$ and we call that vectoral quantity the *electric force* on q. It is defined by:

$$\boldsymbol{F}_E = q \cdot \boldsymbol{E}$$

5.2. The Electrostatic Interaction between Point Charges at Rest

It is evident that a *virtual gravitational field* $\boldsymbol{E}_g$ will have the same effect on a particle with rest mass m_0 and charge q as the electric field $\boldsymbol{E}$ on condition that $\boldsymbol{F}_G$, the gravitational force exerted by $\boldsymbol{E}_g$ on m_0, equals the electric force exerted by $\boldsymbol{E}$ on q, thus on condition that $\boldsymbol{F}_G = \boldsymbol{F}_E$.

According to §10 of "*Acke A. Newton's Law of Universal Gravitation explained by the Theory of Informatons.*" [3] $\boldsymbol{F}_G$, the gravitational force exerted on the particle by the virtual gravitational field $\boldsymbol{E}_g$ is $\boldsymbol{F}_G = m_0 \cdot \boldsymbol{E}_g$ and according to §5.1 $\boldsymbol{F}_E$, the electric force exerted by the electric field is $\boldsymbol{F}_E = q \cdot \boldsymbol{E}$. It follows *that the effect of the virtual gravitational field* $\boldsymbol{E}_g$ *on the particle will be identical to the effect of the electric field* $\boldsymbol{E}$ *on condition that the virtual gravitational field be defined by the relation*:

$$\boldsymbol{E}_g = \frac{q}{m_0} \cdot \boldsymbol{E}$$

According to §9 of the cited paper a particle with rest mass m_0 anchored at a point in a gravitational field $\boldsymbol{E}_g$ is subjected to a tendency to move in the direction defined by $\boldsymbol{E}_g$. Once the anchorage is broken, it acquires a vectoral acceleration that equals $\boldsymbol{E}_g$.

Because a particle with rest mass m_0 and charge q reacts on an electric field $\boldsymbol{E}$ in exactly the same way as on a virtual gravitational field $\boldsymbol{E}_g = \frac{q}{m_0}\boldsymbol{E}$, we conclude: *A particle with rest mass* m_0 *and electric charge* q *anchored at a point in an electric field is subjected to a tendency to move in the direction defined by*

$\boldsymbol{E}$, *the e-field at that point. Once the anchorage is broken, the particle acquires a vectoral acceleration* $\boldsymbol{a}$ *that equals* $\frac{q}{m_0}\boldsymbol{E}$.

It follows: The electric force on a free point charge q in an electric field $\boldsymbol{E}$ causes that the point charge—as predicted by Newton's second law—accelerates according the law:

$$\boldsymbol{F}_E = q \cdot \boldsymbol{E} = q \cdot \frac{m_0}{q} \cdot \boldsymbol{E}_g = m_0 \cdot \boldsymbol{a}$$

5.3. Coulomb's Law

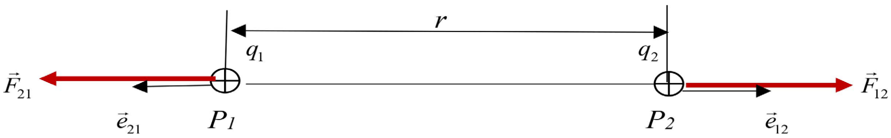

Figure 3. Coulomb's law.

In **Figure 3**, we consider two point charges q_1 and q_2 anchored at the points P_1 and P_2 in an inertial reference frame.

1) q_1 creates and maintains an electric field that at P_2 is defined by the e-field:

$$\boldsymbol{E}_2 = \frac{q_1}{4 \cdot \pi \cdot \varepsilon_0 \cdot r^2} \cdot \boldsymbol{e}_{12}$$

This e-field exerts a force on q_2:

$$\boldsymbol{F}_{12} = q_2 \cdot \boldsymbol{E}_2 = \frac{q_2 \cdot q_1}{4 \cdot \pi \cdot \varepsilon_0 \cdot r^2} \cdot \boldsymbol{e}_{12}$$

2) In a similar manner we find $\boldsymbol{F}_{21}$:

$$\boldsymbol{F}_{21} = -\frac{q_1 \cdot q_2}{4 \cdot \pi \cdot \varepsilon_0 \cdot r^2} \cdot \boldsymbol{e}_{21} = -\boldsymbol{F}_{21}$$

This is the mathematical expression of "*Coulomb's law*" (§3.2).

6. The Electric Field of a Point Charge Moving with Constant Velocity

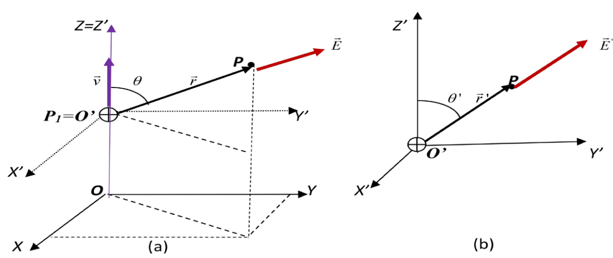

Figure 4. The e-field of a point charge moving with constant velocity.

In **Figure 4(a)** we consider an electrically (positively) charged particle that is moving with constant velocity $\boldsymbol{v} = v \cdot \boldsymbol{e}_z$ along the Z-axis of an IRF $\boldsymbol{O}$. We assume that its rest mass m_0 and its charge q are independent of $\boldsymbol{v}$. At the moment $t = 0$, it passes at the origin O and at the moment $t = t$ at the point P_1. It is evident that

$$OP_1 = z_{P_1} = v \cdot t$$

P is an arbitrary fixed point in $\boldsymbol{O}$. Its position relative to the moving particle is determined by the time dependent position vector $\boldsymbol{r} = \boldsymbol{P_1 P}$.

In Figure 4(b) we introduce $\boldsymbol{O'}$, the proper IRF of the particle, *i.e.* the IRF whose origin O' is anchored to the particle and we assume that $t = t' = 0$ when O' passes through O. Relative to $\boldsymbol{O'}$, the position of P is determined by the time dependent position vector $\boldsymbol{r'} = \boldsymbol{O'P}$.

The point charge q is at rest at the origin of $\boldsymbol{O'}$. So relative to $\boldsymbol{O'}$, $\boldsymbol{E'}$—the electric field vector that characterizes the e-field generated by q at P—is, according to §4.2, completely defined by the vectoral quantity:

$$\boldsymbol{E'} = \frac{q}{4\pi\varepsilon_0 \cdot r'^3} \cdot \boldsymbol{r'}$$

Bij definition $\boldsymbol{E'}$ is—relative to $\boldsymbol{O'}$—the density of the e-information flow at P and the magnitude of $\boldsymbol{E'}$ is the rate per unit area at which e-information flows through an elementary surface $\mathrm{d}S'$ that at P is perpendicular to the velocity $\boldsymbol{c}$ of the informatons that constitute that flow. Thus, the components of $\boldsymbol{E'}$ at P are the densities of the flows of e-information respectively through a surface element $\mathrm{d}y' \cdot \mathrm{d}z'$ perpendicular to the X'-axis, through a surface element $\mathrm{d}z' \cdot \mathrm{d}x'$ perpendicular to the Y'-axis and through a surface element $\mathrm{d}x' \cdot \mathrm{d}y'$ perpendicular to the Z'-axis. And the rates at which the particle sends information through these different surface elements at P are:

$$E'_{x'} \cdot \mathrm{d}y' \cdot \mathrm{d}z' = \frac{q}{4\pi\varepsilon_0 \cdot r'^3} \cdot x' \cdot \mathrm{d}y' \cdot \mathrm{d}z'$$

$$E'_{y'} \cdot \mathrm{d}z' \cdot \mathrm{d}x' = \frac{q}{4\pi\varepsilon_0 \cdot r'^3} \cdot y' \cdot \mathrm{d}z' \cdot \mathrm{d}x'$$

$$E'_{z} \cdot \mathrm{d}x' \cdot \mathrm{d}y' = \frac{q}{4\pi\varepsilon_0 \cdot r'^3} \cdot z' \cdot \mathrm{d}x' \cdot \mathrm{d}y'$$

The Lorentz transformation equations [8] provide the key for the mathematical deduction of $\boldsymbol{E}$—the electric field vector at P relative to $\boldsymbol{O}$—from $\boldsymbol{E'}$, the electric field vector relative to $\boldsymbol{O'}$.

1) With $\beta = \frac{v}{c}$, the Cartesian coordinates of P in the frames $\boldsymbol{O}$ and $\boldsymbol{O'}$ are related to each other by:

$$x' = x \quad y' = y \quad z' = \frac{z - v \cdot t}{\sqrt{1-\beta^2}} = \frac{z - z_{P_1}}{\sqrt{1-\beta^2}}$$

2) The line elements by:

$$\mathrm{d}x' = \mathrm{d}x \quad \mathrm{d}y' = \mathrm{d}y \quad \mathrm{d}z' = \frac{\mathrm{d}z}{\sqrt{1-\beta^2}}$$

3) And further:

$$r' = r \cdot \frac{\sqrt{1-\beta^2 \cdot \sin^2\theta}}{\sqrt{1-\beta^2}}$$

Substitution leads to the following expressions for the rates at which the moving particle sends—relative to ***O***—e-information in the positive direction through the surface elements dy·dz, dz·dx and dx·dy at P:

$$\frac{q}{4\pi\varepsilon_0 \cdot r^3} \cdot \frac{1-\beta^2}{\left(1-\beta^2 \cdot \sin^2\theta\right)^{\frac{3}{2}}} \cdot x \cdot \mathrm{d}y \cdot \mathrm{d}z$$

$$\frac{q}{4\pi\varepsilon_0 \cdot r^3} \cdot \frac{1-\beta^2}{\left(1-\beta^2 \cdot \sin^2\theta\right)^{\frac{3}{2}}} \cdot y \cdot \mathrm{d}z \cdot \mathrm{d}x$$

$$\frac{q}{4\pi\varepsilon_0 \cdot r^3} \cdot \frac{1-\beta^2}{\left(1-\beta^2 \cdot \sin^2\theta\right)^{\frac{3}{2}}} \cdot \left(z - z_{P_1}\right) \cdot \mathrm{d}x \cdot \mathrm{d}y$$

Thus the components of $\boldsymbol{E}$ in the IRF ***O*** are:

$$E_x = \frac{q}{4\pi\varepsilon_0 \cdot r^3} \cdot \frac{1-\beta^2}{\left(1-\beta^2 \cdot \sin^2\theta\right)^{\frac{3}{2}}} \cdot x$$

$$E_y = \frac{q}{4\pi\varepsilon_0 \cdot r^3} \cdot \frac{1-\beta^2}{\left(1-\beta^2 \cdot \sin^2\theta\right)^{\frac{3}{2}}} \cdot y$$

$$E_z = \frac{q}{4\pi\varepsilon_0 \cdot r^3} \cdot \frac{1-\beta^2}{\left(1-\beta^2 \cdot \sin^2\theta\right)^{\frac{3}{2}}} \cdot \left(z - z_{P_1}\right)$$

From which it follows:

$$\boldsymbol{E} = \frac{q}{4\pi\varepsilon_0 r^3} \cdot \frac{1-\beta^2}{\left(1-\beta^2 \cdot \sin^2\theta\right)^{\frac{3}{2}}} \cdot \boldsymbol{r} = \frac{q}{4\pi\varepsilon_0 r^2} \cdot \frac{1-\beta^2}{\left(1-\beta^2 \cdot \sin^2\theta\right)^{\frac{3}{2}}} \cdot \boldsymbol{e}_r$$

We conclude:

1) *A point charge describing a uniform rectilinear movement relative to an inertial reference frame* ***O*** *creates in the space linked to that frame a time dependent electric field. If the charge of the particle is negative,* $\boldsymbol{E}$ *—the electric field vector at P—points at any moment to the actual position of the particle. If it is positive,* $\boldsymbol{E}$ *points in the opposite direction.*

2)

$$E = \frac{|q|}{4\pi\varepsilon_0 r^2} \cdot \frac{1-\beta^2}{\left(1-\beta^2 \cdot \sin^2\theta\right)^{\frac{3}{2}}}$$

E, the magnitude of $\boldsymbol{E}$, denotes the local flux density of e-information at point P; it quantifies the rate per unit area at which a charge emits e-information through an infinitesimal surface element at P, oriented perpendicular to $\boldsymbol{E}$.

Accordingly, the total flux of e-information through any closed surface enclosing a charge q satisfies:

$$\oiint \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{S} = \frac{q}{\varepsilon_0}$$

This result agrees with the law of conservation of e-information: the rate at which e-information escapes from an enclosed space is completely determined by the rate at which it is generated inside that space.

7. The Magnetic Field of a Point Charge Moving with Constant Velocity

7.1. The Emission of Informatons by a Point Charge Moving with Constant Velocity

In Figure 5 we consider a (positive) point charge q moving with constant velocity $\boldsymbol{v}$ along the Z-axis of an IRF $\boldsymbol{O}$. At the arbitrary moment t it passes at P_1. The position of P, an arbitrary fixed point in space, is defined by the vector $\boldsymbol{r} = \boldsymbol{P_1P}$. Because the position of P_1 is continuously changing, $\boldsymbol{r}$ —just like the distance r and the angle θ—is time dependent.

The informatons that—with the speed of light—at the moment t are passing by P, are emitted when the particle was at P_0. Bridging the distance $P_0P = r_0$ took the time interval $\Delta t = \frac{r_0}{c}$. During their rush from P_0 to P their emitter moved from P_0 to P_1: $P_0P_1 = v \cdot \Delta t$.

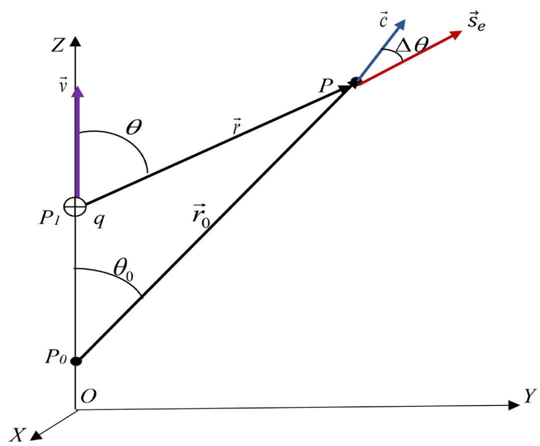

Figure 5. The emission of an informaton by a point charge moving with constant velocity.

1) Rule A.1 of the postulate of the emission of informatons implies that $\boldsymbol{c}$, the velocity of these informatons, points in the direction of their movement, thus along the radius P_0P.

2) Rule C.1 of that postulate implies that $\boldsymbol{s}_e$, their e-index, points away from P_1, the position of the particle at the moment, thus along the radius P_1P, what also can be concluded from the direction of $\boldsymbol{E}$ (§6).

The line carrying $\boldsymbol{s}_e$ and that carrying $\boldsymbol{c}$ form an angle $\Delta\theta$. We call this angle—that is characteristic for the speed of the particle—the "*characteristic angle*" or the "*characteristic deviation*" of the informaton. The quantity $s_b = s_e \cdot \sin(\Delta\theta)$ is called its "*characteristic e-information*" or its "*b-information*" or its "*magnetic* *information*".

We conclude that an informaton emitted by a moving point charge, is a carrier of information referring to the velocity of that point charge. This information is completely characterized by $\boldsymbol{s}_b$, its "*electrical characteristic vector*" or "*b-index*", defined as:

$$\boldsymbol{s}_b = \frac{\boldsymbol{c} \times \boldsymbol{s}_e}{c}$$

1) The b-index is perpendicular to the plane formed by the path of the informaton and the straight line that carries the e-index, thus it is perpendicular to the plane formed by the point P and the path of the emitter.

2) Its orientation relative to that plane is defined by the "rule of the corkscrew".

3) The magnitude of the b-index is $s_b = s_e \cdot \sin(\Delta\theta)$.

In the case of **Figure 5** the b-index points in the opposite direction of the X-axis. In the case of a negative point charge it would have the same orientation as that axis.

7.2. The Magnetic Field Vector—General Definition

If they are emitted by a moving point charge, regardless of whether the speed is constant or variable, all elements of the cloud of informatons in a volume element dV carry, besides e-information, also b-information. The b-information is in any case characterized by the b-indices $\boldsymbol{s}_b$ defined as:

$$\boldsymbol{s}_b = \frac{\boldsymbol{c} \times \boldsymbol{s}_e}{c}$$

So, on the macroscopic level the cloud of informatons generated by a moving point charge manifests itself—in addition to a cloud of e-information—as cloud of b-information called the "*b-field*" or "*the magnetic field*".

If n is the density at P of the cloud of informatons (number of informatons per unit volume) at the moment t, the density of the cloud of b-information (characteristic information per unit volume) at P is characterized by:

$$n \cdot \boldsymbol{s}_b = n \cdot \frac{\boldsymbol{c} \times \boldsymbol{s}_e}{c}$$

We call this (time dependent) vectoral quantity—that will be represented by $\boldsymbol{B}$—the "*magnetic field vector*" at P. B, its magnitude, characterizes the density of the b-information cloud at P and its orientation refers to the orientation of the b-indices $\boldsymbol{s}_b$ of the informatons passing by that point. So, the magnetic field vector that characterizes the magnetic or b-field generated at P by a moving point charge q is:

$$\boldsymbol{B} = n \cdot \frac{\boldsymbol{c} \times \boldsymbol{s}_e}{c} = \frac{\boldsymbol{c}}{c} \times (n \cdot \boldsymbol{s}_e)$$

N—the density of the flow of informatons at P (the rate per unit area at which the informatons cross an elementary surface perpendicular to the direction of their movement) and n (the density of the cloud of informatons at that point, *i.e.* the number of informatons per unit volume) are connected by the relation: $n = \dfrac{N}{c}$.

So, with $\boldsymbol{E} = N \cdot \boldsymbol{s}_e$ we can express the magnetic field vector at P as:

$$\boldsymbol{B} = \frac{\boldsymbol{c}}{c^2} \times \left(N \cdot \boldsymbol{s}_e\right) = \frac{\boldsymbol{c} \times \boldsymbol{E}}{c^2}$$

Conclusion: *A moving point charge is the source of an "electromagnetic field" (an EM-field); a dual entity always consisting of an electric field and a magnetic field, that respectively are characterized by the "electric field vector"* $\boldsymbol{E}$ *and the "magnetic field vector"* $\boldsymbol{B}$.

7.3. The Magnetic Field Vector of a Point Charge Moving with Constant Velocity

We refer to §7.1 (**Figure 5**). Applying the sine-rule to the triangle P_0P_1P, we obtain:

$$\frac{\sin\left(\Delta\theta\right)}{v \cdot \Delta t} = \frac{\sin\theta}{c \cdot \Delta t}$$

From which it follows:

$$s_b = s_e \cdot \frac{v}{c} \cdot \sin\theta$$

Thus, taking into account the orientation of the different vectors, the b-index of an informaton emitted by a point charge moving with constant velocity, can be expressed as:

$$\boldsymbol{s}_b = \frac{\boldsymbol{v} \times \boldsymbol{s}_e}{c}$$

From the general definition of $\boldsymbol{B}$ in §7.2 it follows that in the particular case of an electrically charged particle moving with constant velocity $\boldsymbol{v}$:

$$\boldsymbol{B} = \frac{\boldsymbol{v}}{c^2} \times \left(N \cdot \boldsymbol{s}_e\right) = \frac{\boldsymbol{v} \times \boldsymbol{E}}{c^2}$$

Taking the conclusion of §6 into account, the magnetic field vector at P is:

$$\boldsymbol{B} = \frac{\mu_0 \cdot q}{4\pi r^3} \cdot \frac{1-\beta^2}{\left(1-\beta^2 \cdot \sin^2\theta\right)^{\frac{3}{2}}} \cdot \left(\boldsymbol{v} \times \boldsymbol{r}\right)$$

With: $\mu_0 = \dfrac{1}{c^2 \cdot \varepsilon_0} = 1.26 \times 10^{-6}\ \text{H/m}$

We conclude: *A point charge describing a uniform rectilinear movement relative to an IRF* ***O****, creates in the space linked to that frame a time dependent magnetic field characterized by the magnetic field vector* $\boldsymbol{B}$:

1) *The magnitude of* $\boldsymbol{B}$ *is*:

$$B = \frac{\mu_0 \cdot |q|}{4\pi r^2} \cdot \frac{1-\beta^2}{\left(1-\beta^2 \cdot \sin^2\theta\right)^{\frac{3}{2}}} \cdot v \cdot \sin\theta$$

2) *If the charge of the particle is negative, the orientation of* $\boldsymbol{B}$ *at P is at any moment determined by the orientation of the vectoral product* $\left(\boldsymbol{r} \times \boldsymbol{v}\right)$. *If it is positive,* $\boldsymbol{B}$ *points in the opposite direction.*

8. The Electromagnetic Field of a Point Charge Moving with Constant Velocity

A point charge *q*, moving with constant velocity $\boldsymbol{v} = v \cdot \boldsymbol{e}_z$ along the *Z*-axis of an IRF, creates and maintains an expanding cloud of informatons that are carriers of e- and b-information. That cloud manifests itself as a time dependent continuum: the *electromagnetic field* (*EM-field*) of the particle. It is characterized by two time dependent vectoral quantities: the "electric field vector" (short: *e-field vector*) $\boldsymbol{E}$ and the "magnetic field vector" (short: *b-field vector*) $\boldsymbol{B}$:

$$\boldsymbol{E} = N \cdot \boldsymbol{s}_e = \frac{q}{4\pi\varepsilon_0 r^3} \cdot \frac{1-\beta^2}{\left(1-\beta^2 \cdot \sin^2\theta\right)^{\frac{3}{2}}} \cdot \boldsymbol{r}$$

$$\boldsymbol{B} = n \cdot \boldsymbol{s}_b = \frac{\mu_0 \cdot q}{4\pi r^3} \cdot \frac{1-\beta^2}{\left(1-\beta^2 \cdot \sin^2\theta\right)^{\frac{3}{2}}} \cdot (\boldsymbol{v} \times \boldsymbol{r})$$

One can verify that:

1) $div\boldsymbol{E} = 0$ 2) $div\boldsymbol{B} = 0$

3) $rot\boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t}$ 4) $rot\boldsymbol{B} = \frac{1}{c^2} \cdot \frac{\partial \boldsymbol{E}}{\partial t}$

These relations are the *laws of Maxwell-Heaviside in vacuum*.

If $v \ll c$, the expressions that describe the components of the EM-field reduce to:

$$\boldsymbol{E} = \frac{q}{4\pi\varepsilon_0 r^3} \cdot \boldsymbol{r} \quad \text{and} \quad \boldsymbol{B} = \frac{\mu_0 \cdot q}{4\pi r^3} \cdot (\boldsymbol{v} \times \boldsymbol{r})$$

These non-relativistic results could directly be obtained if one assumes that the displacement of the particle during the time interval that the informatons need to move from the emitter to *P* can be neglected compared to the distance they travel during that period.

9. The Electromagnetic Field of a Set of Moving Point Charges

We consider a set of point charges $q_1, \cdots, q_i, \cdots, q_n$ that at the moment *t* move with velocities $\boldsymbol{v}_1, \cdots, \boldsymbol{v}_i, \cdots, \boldsymbol{v}_n$ relative to an IRF ***O***. It creates and maintains an EM field that, in ***O***, at each point *P* is characterized by the vector pair ($\boldsymbol{E}, \boldsymbol{B}$).

1) Each particle continuously emits e-information and contributes with an amount $\boldsymbol{E}_i$ to the e-field at an arbitrary point *P*. As in §4.3 we conclude that the effective electric field vector at *P* is:

$$\boldsymbol{E} = \sum \boldsymbol{E}_i$$

2) Because it is moving, each particle emits also b-information, contributing to the magnetic field vector at *P* with an amount $\boldsymbol{B}_i$. It is evident that the b-information in the volume element d*V* at *P* at each moment *t* is:

$$\sum \left(\boldsymbol{B}_i \cdot \mathrm{d}V\right) = \left(\sum \boldsymbol{B}_i\right) \cdot \mathrm{d}V$$

Thus, the effective magnetic field vector at P is:

$$\boldsymbol{B} = \sum \boldsymbol{B}_i$$

On the basis of the superposition principle, we can conclude that Maxwell's laws mentioned in §8 remain valid in the case of the electromagnetic field of a set of moving electrically charged particles.

10. The Electromagnetic Field of an Electric Current

10.1. The Electromagnetic Field of a Stationary "Charge Flow"

The term "stationary charge flow" refers to the continuous movement of an electrically charged homogeneous and incompressible fluid that, in an invariable way, flows relative to an IRF. The intensity of a charge flow at an arbitrary point P is characterized by the electric flow density $\boldsymbol{J}_E$. The magnitude of this vectoral quantity at P equals the rate per unit area at which the charge flows through a surface element dS that is perpendicular to the flow at P. By convention, the orientation of $\boldsymbol{J}_E$ is in the direction of that flow if the moving charge is positive and in the opposite direction if it is negative.

If $\mathrm{d}\boldsymbol{l}$ is the vectoral displacement of the volume-element $\mathrm{d}V$ of a stationary charge flow that during $\mathrm{d}t$ passes at an arbitrary point P, its velocity at P is $\boldsymbol{v} = \dfrac{\mathrm{d}\boldsymbol{l}}{\mathrm{d}t}$.

Thus, the electric charge that during $\mathrm{d}t$ passes through $\mathrm{d}S$, the surface element that at P is perpendicular to $\mathrm{d}\boldsymbol{l}$, fills the volume $\mathrm{d}V = \mathrm{d}S{\cdot}\mathrm{d}l$. And with ρ_E the charge density at P, the electric charge in $\mathrm{d}V$ is

$$\mathrm{d}q = \rho_E \cdot \mathrm{d}V = \rho_E \cdot \mathrm{d}S \cdot \mathrm{d}l = \rho_E \cdot v \cdot \mathrm{d}S \cdot \mathrm{d}t\ .$$

So, the magnitude of the flow density $\boldsymbol{J}_E$ at P is: $|\rho_E| \cdot v$ and:

$$\boldsymbol{J}_E = \rho_E \cdot \boldsymbol{v}$$

The rate at which the flow transports in the positive direction (defined by the orientation of the surface vectors $\mathrm{d}\boldsymbol{S}$) charge through an arbitrary section ΔS of a stationary charge flow, is independent of the section:

$$i_E = \iint_{\Delta S} \boldsymbol{J}_E \cdot \mathrm{d}\boldsymbol{S}$$

i_E is the *intensity of the charge flow*.

Since a stationary charge flow is the macroscopic manifestation of moving charge elements $\rho_E \cdot \mathrm{d}V$, it creates and maintains an EM field ($\boldsymbol{E}, \boldsymbol{B}$). $\mathrm{d}\boldsymbol{E}$ and $\mathrm{d}\boldsymbol{B}$, the contributions of the charge element at a certain point of the flow to respectively $\boldsymbol{E}$ and $\boldsymbol{B}$ at a certain point P are determined by §8 where $\mathrm{d}q = \rho_E \cdot \mathrm{d}V$. Since the parameters of the charge element at a certain point are time independent, *the EM field of a stationary mass flow will be time independent*.

Therefore, it is evident that the rules for a static e-field (§4.5. and 4.6.) also apply for the time independent electric field of a stationary charge flow:

1) $div\boldsymbol{E} = \dfrac{\rho_E}{\varepsilon_0}$

2) $rot\boldsymbol{E} = 0$ what implies the existence of a scalar vector potential function V

for which $\boldsymbol{E} = -gradV$

And it can be proven [7] that the rules for its time independent b-field are:

1) $div\boldsymbol{B} = 0$ what implies the existence of a vector potential function $\boldsymbol{A}$ for which $\boldsymbol{B} = rot\boldsymbol{A}$

2) $rot\boldsymbol{B} = \nu_0 \cdot \boldsymbol{J}_E$

10.2. The Electromagnetic Field of a Current-Carrying Conductor

With the term "current-carrying conductor", we refer to a stationary charge flow through a—whether or not straight—conductor. If $\mathrm{d}q$ is the elementary quantity of charge that during the elementary time interval $\mathrm{d}t$ flows through ΔS—an arbitrary section of the conductor perpendicular to the flow—the rate at which charge is transported through the conductor in the (arbitrarily chosen) reference direction, is:

$$i = \frac{\mathrm{d}q}{\mathrm{d}t}$$

This algebraic[4] quantity is called the *electric current through the conductor*.

In the case of a cylindrical conductor, the charge elements $\mathrm{d}q$ that constitute the current are moving parallel to the axis with velocity v. We can identify a cylindrical conductor—a wire—as a string through which a current i flows. Each moving charge element is contained in a line element $\mathrm{d}\boldsymbol{l}$ of the string[5]. The quantities that are relevant for the electric current in the string are related by:

$$\boldsymbol{v} \cdot \mathrm{d}q = \frac{\mathrm{d}\boldsymbol{l}}{\mathrm{d}t} \cdot i \cdot \mathrm{d}t = i \cdot \mathrm{d}\boldsymbol{l}$$

$i \cdot \mathrm{d}\boldsymbol{l}$ is called a *current element*.

The magnetic induction $\mathrm{d}\boldsymbol{B}$, caused at a point P by a current element is found by substituting $\boldsymbol{v} \cdot \mathrm{d}q$ by $i \cdot \mathrm{d}\boldsymbol{l}$ in the formula that we derived on §7.3 for a moving point charge. ($\boldsymbol{r}$ defines the position of P relative to the considered current element). So:

$$\mathrm{d}\boldsymbol{B} = \frac{\mu_0 \cdot i}{4\pi r^3} \cdot \frac{1-\beta^2}{\left(1-\beta^2 \cdot \sin^2\theta\right)^{\frac{3}{2}}} \cdot \left(\mathrm{d}\boldsymbol{l} \times \boldsymbol{r}\right)$$

Taking into account that the speed of the charge carriers that constitute the current i is very small relative to the speed of light—what implies that $\beta \ll 1$—this formula in practice takes the following form:

$$\mathrm{d}\boldsymbol{B} = \frac{\mu_0 \cdot i}{4 \cdot \pi \cdot r^3} \cdot \left(\mathrm{d}\boldsymbol{l} \times \boldsymbol{r}\right)$$

This expression is known as "*Biot-Savart's*" law: it determines $\mathrm{d}\boldsymbol{B}$, *the contribution of the current element* $i \cdot \mathrm{d}\boldsymbol{l}$ *of a current-carrying conductor i to the magnetic field vector* $\boldsymbol{B}$ *generated by i* at an arbitrary point *P*.

We can describe the current in a conductor as the drift movement of fictive

[4] $i > 0$ if the current is transporting positive charge in the direction of the priori chosen reference direction.

[5] $\mathrm{d}\boldsymbol{l}$ is oriented according to the reference direction of *i*.

positive charge carriers through a lattice of immobile negative charged entities. *A conductor in which an electric current flows causes a magnetic field, but not an electric one*. Indeed, the current is a charge flow and thus the cause of a magnetic field composed by contributions defined by Biot-Savart's law. A current carrying conductor doesn't cause an electric field, because the e-field caused by the moving charge carriers is neutralized by the e-field caused by the fixed lattice. We conclude: *Unlike a gravitomagnetic field* [4]—*that never exists without a gravitational field—a magnetic field can exist without an electric field that masks its effects*.

At a point at a distance r from a long straight wire carrying a current i, the magnetic field $\boldsymbol{B}$ generated by that wire can easily be deduced from Biot-Savart's law by an integration process: $\boldsymbol{B}$ is linked to the sense of the current by the rule of the corkscrew and its magnitude is determined by:

$$B = \frac{\mu_0 \cdot i}{2\pi r}$$

From this version of Biot-Savart's law it can be deduced that $\oint_L \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{l}$ calculated along a closed path L, only depends on the electric current ($\sum i_{in}$) encircled by that path (*Ampère's law*):

$$\oint_L \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{l} = \mu_0 \cdot \sum i_{in}$$

11. The Electromagnetic Field of a Uniformly Accelerated Point Charge

11.1. The Emission of Informatons by a Uniformly Accelerated Point Charge

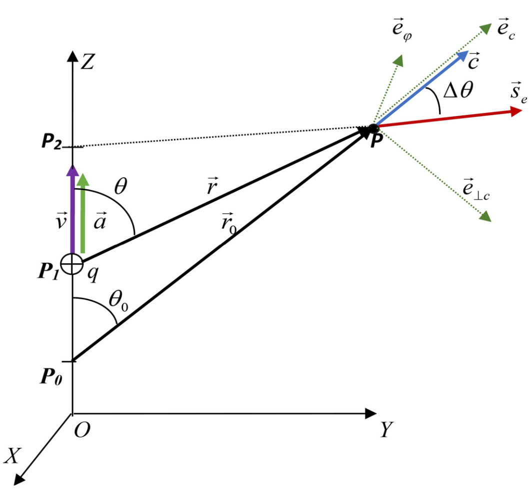

Figure 6. The emission of informatons by an accelerated point charge.

In Figure 6 we consider a (positive) point charge q that, during a finite time interval, moves relative to the IRF $\boldsymbol{O}$ with constant acceleration $\boldsymbol{a} = a \cdot \boldsymbol{e}_z$. At the moment $t = 0$, q starts from rest at the origin O and at $t = t$ it passes by the point

P_1. Its velocity is defined by $\boldsymbol{v} = v \cdot \boldsymbol{e}_z = a \cdot t \cdot \boldsymbol{e}_z$, and its position by

$$z = \frac{1}{2} \cdot a \cdot t^2 = \frac{1}{2} \cdot v \cdot t$$

We limit our considerations to the situation where the speed of the particle remains much smaller than the speed of light.

The informatons that during the infinitesimal time interval $(t,\ t + \mathrm{d}t)$ pass by the fixed point P (whose position relative to the moving point charge q is defined by the time dependent position vector r) have been emitted at the moment $t_0 = t - \Delta t$, when q with velocity $\boldsymbol{v}_0 = v_0 \cdot \boldsymbol{e}_z$ passed by P_0. The position of P relative to P_0 is defined by the time dependent position vector $\boldsymbol{r}_0 = \boldsymbol{r}(t - \Delta t)$. Δt, the time interval during which q moves from P_0 to P_1 is the period that the informatons need to move from P_0 to P from which we can conclude that

$$\Delta t = \frac{r_0}{c} \quad \text{and} \quad v_0 = v(t - \Delta t) = v\left(t - \frac{r_0}{c}\right) = v - a \cdot \frac{r_0}{c}.$$

Between the moments $t = t_0$ and $t = t_0 + \Delta t$, q is moving from P_0 to P_1. That movement can be considered as the superposition of a uniform movement with constant speed $v_0 = v(t - \Delta t)$ and a uniformly accelerated movement with constant acceleration a.

1) In **Figure 7** we consider the case of the point charge q that between the moments $t = t_0$ and $t = t_0 + \Delta t$ is moving with constant speed v_0 along the Z-axis.

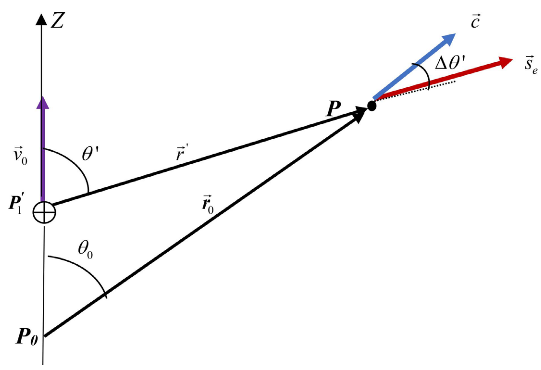

Figure 7. q is moving with constant speed v_0.

At the moment $t_0 = t - \Delta t$, q passes by P_0 and at the moment t by P_1':

$$P_0 P_1' = v_0 \cdot \Delta t = v_0 \frac{r_0}{c}. \tag{1}$$

The informatons that, during the infinitesimal time interval $(t,\ t + \mathrm{d}t)$, pass by the point P—whose position relative to the q at the moment t is defined by the position vector $\boldsymbol{r}'$—have been emitted at the moment t_0 when q passed at P_0. Their velocity $\boldsymbol{c}$ is along $\boldsymbol{r}_0$ and their e-index $\boldsymbol{s}_e$ along $\boldsymbol{r}'$.

2) In **Figure 8** we consider the case of the point charge q starting at rest at P_0 that between the moments $t = t_0$ and $t = t_0 + \Delta t$ is moving with constant accel-

eration $\boldsymbol{a}$ along the Z-axis.

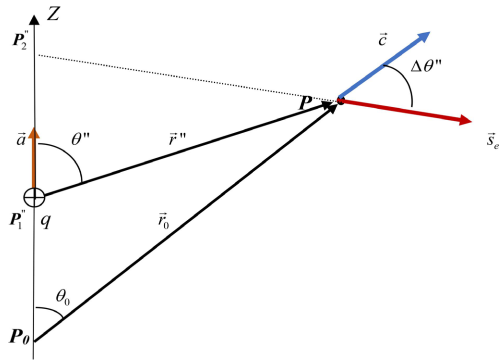

Figure 8. q is moving with constant acceleration a.

At the moment $t_0 = t - \Delta t$ it is at P_0 and at the moment t at P_1'':

$$P_0P_1'' = \frac{1}{2}\cdot a\cdot(\Delta t)^2 = \frac{1}{2}\cdot a\cdot\frac{r^2}{c^2}$$

The informatons that during the infinitesimal time interval (t, $t + \mathrm{d}t$) pass by the point P (whose position relative to the uniformly accelerated point charge q is at t defined by the position vector $\boldsymbol{r}''$) have been emitted at the moment t_0 when q was at P_0. Their velocity $\boldsymbol{c}$ is along $\boldsymbol{r}_0$. To determine the orientation of $\boldsymbol{s}_e$ we consider in **Figure 9** the trajectory—relative to the accelerated reference frame $OX'Y'Z'$ that is anchored to q—of the informatons that at t_0 are emitted in the direction of P ($\alpha = \frac{\pi}{2} - \theta_0$).

Relative to $OX'Y'Z'$ these informatons are accelerated with an amount $-\boldsymbol{a}$: they follow a parabolic trajectory (**Figure 9**) described by the equation:

$$z' = \mathrm{tg}\alpha\cdot y' - \frac{1}{2}\cdot\frac{a}{c^2\cdot\cos^2\alpha}\cdot y'^2$$

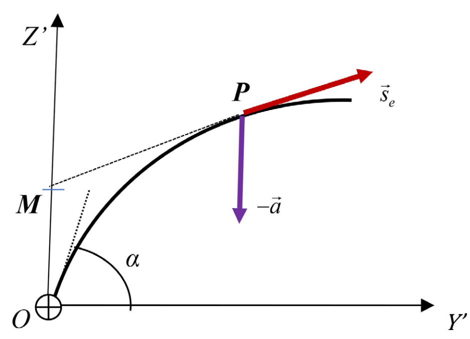

Figure 9. Trajectory of the informatons relative to $OX'Y'Z'$.

At the moment $t = t_0 + \Delta t$, when they pass by P, the tangent line to that trajectory cuts the Z'-axis at the point M. It's easy to show that:

$$z'_M = \frac{1}{2}\cdot a\cdot(\Delta t)^2 = \frac{1}{2}\cdot a\cdot\frac{r_0^2}{c^2}$$

That means that the orientation of the e-indices of the informatons that at the moment t pass by P (**Figure 8**), is determined by the position of the point M on the Z'-axis that has a lead of

$$P_1''P_2'' = P_0M = \frac{1}{2}\cdot a\cdot(\Delta t)^2 = \frac{1}{2}\cdot a\cdot\frac{r_0^2}{c^2}$$

on P_1'', the position of the point charge at the moment t. And since $P_0P_2'' = P_0P_1'' + P_1''P_2''$, we conclude that:

$$P_0P_2'' = a\cdot\frac{r_0^2}{c^2} \tag{2}$$

In the inertial reference frame $\boldsymbol{O}$ (**Figure 6**) the orientation of $\boldsymbol{s}_e$ is determined by the position of the point P_2 on the Z-axis determined by the superposition of the effect of the velocity (1) and the effect of the acceleration (2) of q:

$$P_0P_2 = P_0P_1' + P_0P_2'' = \frac{v_0}{c}\cdot r_0 + \frac{a}{c^2}\cdot r_0^2 \tag{3}$$

The carrier line of the e-index $\boldsymbol{s}_e$ of an informaton that—relative to the IRF $\boldsymbol{O}$—at the moment t passes by P forms a "characteristic angle" $\Delta\theta$ with the carrier line of its velocity vector $\boldsymbol{c}$, that can be deduced by application of the sine-rule in triangle P_0P_2P (**Figure 6**):

$$\frac{\sin(\Delta\theta)}{P_0P_2} = \frac{\sin\theta}{r_0} \tag{4}$$

From (3) and (4) it follows that

$$\sin(\Delta\theta) = \frac{v_0}{c}\cdot\sin\theta + \frac{a}{c^2}\cdot r_0\cdot\sin\theta$$

From the fact that P_0P_1—the distance travelled by q during the time interval Δt—can be neglected relative to P_0P—the distance travelled by light during the same period—it follows that that $r_0 \approx r$. So:

$$\sin(\Delta\theta) \approx \frac{v_0}{c}\cdot\sin\theta + \frac{a}{c^2}\cdot r\cdot\sin\theta$$

From **Figure 6** we can conclude that the e-index $\boldsymbol{s}_e$ of an informaton that at the moment t passes by P, has a longitudinal component—this is a component in the direction of $\boldsymbol{c}$ (its velocity vector)—and a transverse component—this is a component perpendicular to that direction. Introducing the reference frame defined by ($\boldsymbol{e}_c, \boldsymbol{e}_{\perp c}, \boldsymbol{e}_\varphi$) and noting that in this context s_e is an algebraic quantity that has the same sign as q:

$$\boldsymbol{s}_e = s_e\cdot\cos(\Delta\theta)\cdot\boldsymbol{e}_c + s_e\cdot\sin(\Delta\theta)\cdot\boldsymbol{e}_{\perp c}$$

And because $\cos(\Delta\theta)\approx 1$, the e-index of an informaton emitted by the accelerated point charge is:

$$\boldsymbol{s}_e = s_e\cdot\boldsymbol{e}_c + s_e\cdot\left(\frac{v_0}{c}\cdot\sin\theta + \frac{a}{c^2}\cdot r\cdot\sin\theta\right)\cdot\boldsymbol{e}_{\perp c} \tag{5}$$

From the definition of the b-index (§7.1), we deduce its b-index:

$$s_b = \frac{s_e}{c} \cdot \left(v_0 + \frac{a \cdot r}{c} \right) \cdot \sin\theta \cdot \boldsymbol{e}_\varphi \tag{6}$$

with $\boldsymbol{e}_\varphi = \boldsymbol{e}_c \times \boldsymbol{e}_{\perp c}$ (Figure 6).

11.2. The Electromagnetic Field of an Accelerated Point Charge

The informatons that, at the moment t, are passing by the fixed point P—defined by the time dependent position vector $\boldsymbol{r}$ —are emitted when q was at P_0 (Figure 6). Their velocity $\boldsymbol{c}$ is on the same carrier line as $\boldsymbol{r}_0 = \boldsymbol{P}_0\boldsymbol{P}$. Their e-index is on the carrier line P_2P. They constitute an EM field.

1) With N the density of the flow of informatons at P (the rate per unit area at which the informatons cross an elementary surface perpendicular to the direction of their movement), the electric field vector at that point is $\boldsymbol{E} = N \cdot \boldsymbol{s}_e$.

According to §11.1: $\boldsymbol{s}_e = s_e \cdot \boldsymbol{e}_c + s_e \cdot \left(\frac{v_0}{c} \cdot \sin\theta + \frac{a}{c^2} \cdot r \cdot \sin\theta \right) \cdot \boldsymbol{e}_{\perp c}$

With $s_e = \frac{q}{m_0} \cdot \frac{1}{K \cdot \varepsilon_0}$ (§3.1), $N = \frac{K \cdot m_0}{4 \cdot \pi \cdot r^2}$ (§4.1) and $\mu_0 = \frac{1}{\varepsilon_0 \cdot c^2}$ (§7.3) we obtain:

$$\boldsymbol{E} = \frac{q}{4\pi\varepsilon_0 \cdot r^2} \cdot \boldsymbol{e}_c + \left[\frac{q}{4\pi\varepsilon_0 \cdot c \cdot r^2} \cdot v_0 \cdot \sin\theta + \frac{\mu_0 \cdot q}{4\pi \cdot r} \cdot a \cdot \sin\theta \right] \cdot \boldsymbol{e}_{\perp c}$$

2) With n the density of the cloud of informatons at P (the number of informatons per unit volume), the magnetic field vector at that point is $\boldsymbol{B} = n \cdot \boldsymbol{s}_b$.

According to §11.1: $\boldsymbol{s}_b = \frac{s_e}{c} \cdot \left(v_0 + \frac{a \cdot r}{c} \right) \cdot \sin\theta \cdot \boldsymbol{e}_\varphi$

With $s_e = \frac{q}{m_0} \cdot \frac{1}{K \cdot \varepsilon_0}$ (§3.1), $n = \frac{K \cdot m_0}{4 \cdot \pi \cdot c \cdot r^2}$ (§7.2) and $\mu_0 = \frac{1}{\varepsilon_0 \cdot c^2}$ (§7.3) we obtain:

$$\boldsymbol{B} = \left[\frac{\mu_0 \cdot q}{4\pi r^2} \cdot v_0 \cdot \sin\theta + \frac{\mu_0 \cdot q}{4\pi c \cdot r} \cdot a \cdot \sin\theta \right] \cdot \boldsymbol{e}_\varphi$$

The formulas for $\boldsymbol{E}$ and $\boldsymbol{B}$ are derived under the assumption that the point charge describes a motion with constant acceleration and that its speed remains negligible compared to the speed of light. In the context of these assumptions, they also describe the situation when a is time dependent. Indeed, during the period Δt that the informatons need to bridge the distance between P_0 and P, the speed and the acceleration of their source can be considered as constant, respectively

$$v_0 = v\left(t - \frac{r}{c} \right) \quad \text{and} \quad a_0 = a\left(t - \frac{r}{c} \right).$$

We conclude: *The EM field of an accelerating point charge is a dual entity defined by the vector pair* ($\boldsymbol{E}, \boldsymbol{B}$). *It is determined by the expressions*:

$$\boldsymbol{E} = \frac{q}{4\pi\varepsilon_0 \cdot r^2} \cdot \boldsymbol{e}_c + \left[\frac{q}{4\pi\varepsilon_0 \cdot c \cdot r^2} \cdot v\left(t - \frac{r}{c} \right) \cdot \sin\theta + \frac{\mu_0 \cdot q}{4\pi \cdot r} \cdot a\left(t - \frac{r}{c} \right) \cdot \sin\theta \right] \cdot \boldsymbol{e}_{\perp c}$$

$$\boldsymbol{B}=\left[\frac{\mu_0\cdot q}{4\pi\cdot r^2}\cdot v\left(t-\frac{r}{c}\right)\cdot\sin\theta+\frac{\mu_0\cdot q}{4\cdot\pi\cdot c\cdot r}\cdot a\left(t-\frac{r}{c}\right)\cdot\sin\theta\right]\cdot\boldsymbol{e}_{\varphi}$$

And $\dfrac{1}{\mu_0\cdot\varepsilon_0}=c^2$

The time dependent components of $\boldsymbol{E}$ and $\boldsymbol{B}$ represent waves traveling with the speed c in the direction of $\boldsymbol{c}$ We say that an accelerated point charge is the source of an "*electromagnetic wave*" $\{\boldsymbol{E},\boldsymbol{B}\}$. Its components are both transverse to $\boldsymbol{c}$ and mutually perpendicular. *From the mathematical expressions derived above, it can be concluded that at a point P, sufficient far from the accelerated particle, the components of the created wave are proportional to* $\dfrac{1}{r}$ *and they are determined by the acceleration of the source at the moment the involved informatons were emitted*:

$$\boldsymbol{E}=\frac{\mu_0\cdot q}{4\pi\cdot r}\cdot a\left(t-\frac{r}{c}\right)\cdot\sin\theta\cdot\boldsymbol{e}_{\perp c}$$

$$\boldsymbol{B}=\frac{\mu_0\cdot q}{4\cdot\pi\cdot c\cdot r}\cdot a\left(t-\frac{r}{c}\right)\cdot\sin\theta\cdot\boldsymbol{e}_{\varphi}$$

12. The Interaction between Moving Point Charges—Lorentz's Force Law

12.1. The Electromagnetic Force on a Point Charge Moving in an Electromagnetic Field

We consider a set of point charges moving relative to an IRF $\boldsymbol{O}$. They create and maintain an EM field that at each point of the space linked to $\boldsymbol{O}$ is completely defined by the vectors $\boldsymbol{E}$ and $\boldsymbol{B}$. Each particle is "immersed" in a cloud of informatons carrying both e- and b-information. At each point, except at its own position, each particle contributes to the construction of that cloud.

Let us focus on point charge q that, at the moment t, passes with velocity v by the point P.

1) If the other particles were not there $[\boldsymbol{E}]$—the electric field in the immediate vicinity of q – would—according to §6—be symmetric relative to the carrier line of the velocity $\boldsymbol{v}$ of q. In reality this is not the case: the emission of e-information by the other point charges is responsible for the disturbance of the "characteristic symmetry" of the electric field in the vicinity of q. Because $\boldsymbol{E}$ at P is the density of the flow of e-information send to P by the other charges, it is a measure for the extent to which that characteristic symmetry in the immediate vicinity of P is disturbed.

2) If the other particles were not there $[\boldsymbol{B}]$—the magnetic field in the immediate vicinity of q—would, according to §7.3 "rotate" around the carrier line of the velocity v of q. This implies that the pseudo electric field $\boldsymbol{v}\times[\boldsymbol{B}]$ would be symmetric relative to that carrier line. In reality this is not the case: the emission of b-information by the other point charges is responsible for the disturbance of the "characteristic symmetry" of the magnetic field and thus for the disturbance

of the "characteristic symmetry" of the pseudo electric field of *q*: the vector product ($\boldsymbol{v}\times\boldsymbol{B}$) is a measure for the extent to which this occurs in the immediate vicinity of the *P*.

So, the *characteristic symmetry* of the cloud of e/b-information around a moving point charge—*i.e.* (the symmetry of the EM self-field) is in the immediate vicinity of that particle disturbed by $\boldsymbol{E}$ regarding the electric self-field and by ($\boldsymbol{v}\times\boldsymbol{B}$) regarding the magnetic self-field, thus by the effective pseudo electric field $\boldsymbol{E}+(\boldsymbol{v}\times\boldsymbol{B})$.

In line with §5.2: *when a charged particle can freely move, it reacts to the disturbance by an external electromagnetic field by accelerating so that the field's influence on its motion is fully expressed in its acceleration*. In its proper IRF, the particle perceives only its own symmetric self-field and becomes "blind" to the external field.

This reaction requires that a point charge *q* in an EM field ($\boldsymbol{E},\boldsymbol{B}$) experiences an action because of that field.

1) That action is proportional to the extent to which the characteristic symmetry of the electromagnetic field in the direct vicinity of *P* is disturbed by the extern electromagnetic field, thus to $\left[\boldsymbol{E}+(\boldsymbol{v}\times\boldsymbol{B})\right]$ at *P*.

2) It depends also on the magnitude of *q*. Indeed, the e/b-information cloud created and maintained by *q* is more compact as *q* is greater. That implies that the disturbing effect on the characteristic symmetry around *q* by the extern EM field is smaller when *q* is greater. Thus, to impose a certain acceleration, the action of the electric field on *q* must be greater as *q* is greater.

We can conclude that the action that accelerates a particle in an electromagnetic field must be proportional to $\left[\boldsymbol{E}+(\boldsymbol{v}\times\boldsymbol{B})\right]$, the effective pseudo electric field to which the particle is exposed, and to *q*, the electric charge of the particle. We represent that action by $\boldsymbol{F}_{EM}$ and we call it: the force developed by the EM field on the particle or the *electromagnetic force* or the *Lorentz force*. It is defined by:

$$\boldsymbol{F}_{EM}=q\cdot\left[\boldsymbol{E}+(\boldsymbol{v}\times\boldsymbol{B})\right]$$

12.2. The Electromagnetic Interaction between Free Moving Point Charges

It is evident that a *virtual gravitoelectromagnetic field* (*GEM field*) ($\boldsymbol{E}_g,\boldsymbol{B}_g$) will have the same effect on a moving particle with rest mass m_0 and charge *q* as the electromagnetic field ($\boldsymbol{E},\boldsymbol{B}$) on condition that $\boldsymbol{F}_G$, the gravitomagnetic force exerted by ($\boldsymbol{E}_g,\boldsymbol{B}_g$) on m_0, equals the Lorentz force exerted by ($\boldsymbol{E},\boldsymbol{B}$) on *q*, thus on condition that $\boldsymbol{F}_G=\boldsymbol{F}_{EM}$.

$\boldsymbol{F}_{EM}$, the *Lorenz* force exerted by the *EM field* ($\boldsymbol{E},\boldsymbol{B}$) on a particle with rest mass m_0 and charge *q* moving with velocity $\boldsymbol{v}$ *is* $\boldsymbol{F}_{EM}=q\cdot\left[\boldsymbol{E}+(\boldsymbol{v}\times\boldsymbol{B})\right]$, and—according to §10 of ref [4]— $\boldsymbol{F}_G$, the gravitomagnetic force exerted on that particle by a (virtual) GEM field ($\boldsymbol{E}_g,\boldsymbol{B}_g$) is $\boldsymbol{F}_G=m_0\cdot\left[\boldsymbol{E}_g+(\boldsymbol{v}\times\boldsymbol{B}_g)\right]$.

It follows *that the effect of the virtual gravitational field on the particle will be* *identical to the effect of the EM field* (*that* $\boldsymbol{F}_G = \boldsymbol{F}_{EM}$) *on condition that the virtual gravitational field be defined by the relation*:

$$\boldsymbol{E}_g + \left(\boldsymbol{v} \times \boldsymbol{B}_g\right) = \frac{q}{m_0} \cdot \left[\boldsymbol{E} + \left(\boldsymbol{v} \times \boldsymbol{B}\right)\right].$$

Because a particle with rest mass m_0 and charge q reacts on an electromagnetic field ($\boldsymbol{E}, \boldsymbol{B}$) in exactly the same way as on the corresponding virtual GEM field we conclude: *A free particle with rest mass* m_0 *and electric charge* q *moving with velocity* $\boldsymbol{v}$ *in an electromagnetic field* ($\boldsymbol{E}, \boldsymbol{B}$) *is forced to accelerate relative to its proper IRF with an amount*

$$\boldsymbol{a}' = \frac{q}{m_0} \cdot \left[\boldsymbol{E} + \left(\boldsymbol{v} \times \boldsymbol{B}\right)\right]'$$

$\left[\boldsymbol{E} + \left(\boldsymbol{v} \times \boldsymbol{B}\right)\right]'$ *being the virtual gravitational field relative to the proper IRF of the particle*.

Using the appropriate transformation formulas [8], $\boldsymbol{a}'$ —the acceleration relative to its proper IRF ***O'*** – can be expressed in function of the characteristics of the motion of the particle relative to IRF ***O***. In §10 of [4] it is shown that:

$$\boldsymbol{a}' = \frac{\mathrm{d}}{\mathrm{d}t}\left[\frac{\boldsymbol{v}}{\sqrt{1-\beta^2}}\right] = \frac{1}{m_0} \cdot \frac{\mathrm{d}\boldsymbol{p}}{\mathrm{d}t}$$

$\boldsymbol{p} = m \cdot \boldsymbol{v}$ is the *linear momentum of the particle* relative to the IRF ***O*** and m is its *relativistic mass*:

$$m = \frac{m_0}{\sqrt{1-\beta^2}}$$

In §2 of [4] it is shown that m determines the rate at which the particle emits informatons when the time is read on the clock of its proper IRF. The relativistic mass m of a particle is a measure for its inertia *i.e.* its resistance to changes in its state of motion, while its rest mass m_0 is a measure for its capacity to gravitate.

We conclude: *relative to the IRF* ***O***, *the linear momentum* $\boldsymbol{p}$ *of a particle moving in an electromagnetic field* ($\boldsymbol{E}, \boldsymbol{B}$) *with velocity* $\boldsymbol{v}$ *changes according the law*:

$$q \cdot \left[\boldsymbol{E} + \left(\boldsymbol{v} \times \boldsymbol{B}\right)\right] = \frac{\mathrm{d}\boldsymbol{p}}{\mathrm{d}t} \quad \text{with} \quad \boldsymbol{p} = m \cdot \boldsymbol{v}$$

This is "*Lorentz force law*".

12.3. The Electromagnetic Interaction between Two Moving Point Charges

In **Figure 10** we consider two point charges that are anchored in the IRF ***O'*** that is moving relative to IRF ***O*** with constant velocity $\boldsymbol{v} = v \cdot \overline{e}_z$. According to §8 the magnitude of the components of the EM field created and maintained by q_1 at the position of q_2 are determined by:

$$E_2 = \frac{q_1}{4\pi\varepsilon_0 r^2} \cdot \frac{1}{\sqrt{1-\beta^2}} \quad \text{and} \quad B_2 = \frac{q_1}{4\pi\varepsilon_0 r^2} \cdot \frac{1}{\sqrt{1-\beta^2}} \cdot \frac{v}{c^2}$$

$\boldsymbol{E}_2$ points in the direction of the *Y*-axis and $\boldsymbol{B}_2$ points in is opposite to the direction of the *X*-axis.

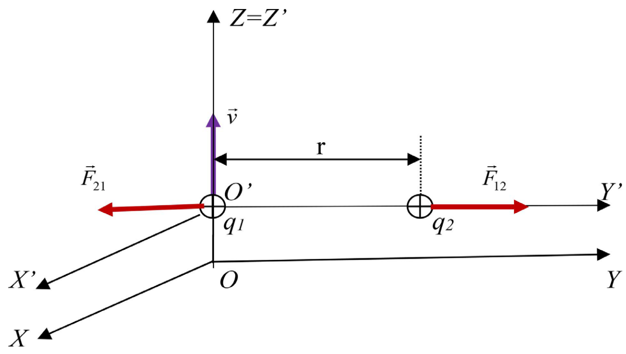

Figure 10. Interaction between two moving point charges.

According to 12.1 the Lorentz force exerted by the EM field ($\boldsymbol{E}_2, \boldsymbol{B}_2$) on q_2 points in the direction of the *Y*-axis and its magnitude is:

$$F_{12} = q_2 \cdot (E_2 - v \cdot B_2)$$

After substitution:

$$F_{12} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 \cdot q_2}{r^2} \cdot \sqrt{1-\beta^2} = F'_{12} \cdot \sqrt{1-\beta^2}$$

With $F'_{12} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 \cdot q_2}{r^2}$ the magnitude of the force that q_1, according to Coulomb's law, in the IRF ***O'***—where both particles are at rest—exerts on q_2.

In the same way we find:

$$F_{21} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 \cdot q_2}{r^2} \cdot \sqrt{1-\beta^2} = F'_{21} \cdot \sqrt{1-\beta^2}$$

We conclude that the moving point charges repulse each other with a force:

$$F = F_{12} = F_{21} = F' \cdot \sqrt{1-\beta^2}$$

Relative to ***O*** both particles are moving with constant speed v in the direction of the *Z*-axis. From the transformation equations between an IRF ***O*** and another IRF ***O'***, in which a point mass experiencing a force *F* is instantaneously at rest, we can immediately deduce *F*, the force that the moving particles exert on each other in ***O*** [8]. The result of that procedure perfectly agrees with what we have deduced above.

From the above we can conclude *that the component of the electromagnetic force due to the magnetic field is β- times smaller than that due to the electric field.* This implies that, for speeds much smaller than the speed of light, the effects of the b-information are masked. This is not the case for EM fields generated by an electric current-carrying conductor where there is only a magnetic induction field.

13. The Electromagnetic Interaction between Electric Line Currents

13.1. A Current Element in an Electromagnetic Field

In §10.2 it is shown that a current element $i \cdot \mathrm{d}\boldsymbol{l}$ is an object that is equivalent to an elementary moving point charge $\boldsymbol{v} \cdot \mathrm{d}q$. That implies that the Lorentz's force on a current element $i \cdot \mathrm{d}\boldsymbol{l}$ in an EM field ($\boldsymbol{E}, \boldsymbol{B}$) has only a magnetic component $\boldsymbol{F}_B$ and that Lorentz's force law reduces to:

$$\boldsymbol{F}_B = i \cdot (\mathrm{d}\boldsymbol{l} \times \boldsymbol{B}) = \frac{\mathrm{d}\boldsymbol{p}}{\mathrm{d}t}$$

13.2. Interaction between Two Parallel Current-Carrying Conductors

Figure 11 shows two long parallel wires anchored in an IRF, separated by a distance r and carrying currents i_1 and i_2. The left wire will produce a magnetic field at all nearby points. At the site of the right wire the magnitude of this field is—according to Biot-Savart's law (§10.2):

$$B_1 = \frac{\mu_0 \cdot i_1}{2\pi r}$$

and it points, as shown, in the plane of the figure.

The magnetic force exerted by that field on the segment with length L of the right wire points, according §13.1, to the left and its magnitude is:

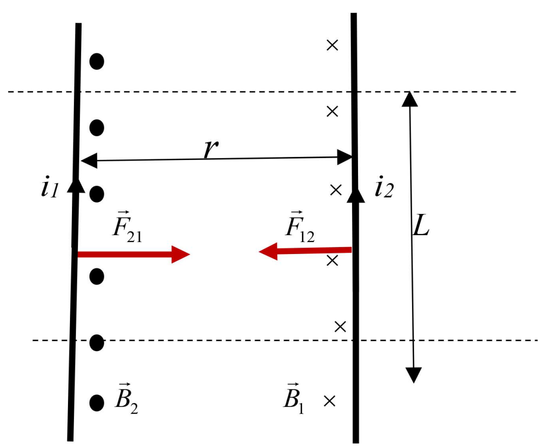

Figure 11. Interaction between two parallel current-carrying conductors.

$$F_{12} = B_1 \cdot L \cdot i_2 = \frac{\mu_0 \cdot i_1 \cdot i_2}{2\pi r} \cdot L$$

In the same way we find that the force exerted by the right wire on het segment with length L of the left one, points to the right and has the magnitude:

$$F_{12} = B_2 \cdot L \cdot i_1 = \frac{\mu_0 \cdot i_2 \cdot i_2}{2\pi r} \cdot L$$

We conclude: *The magnetic forces that two long parallel wires exert on each other are equal and opposite. The force between parallel currents is an attraction and between antiparallel currents it is a repulsion. The magnitude of that force per unit length is in any case*:

$$\frac{F}{L} = \frac{\mu_0 \cdot i_1 \cdot i_2}{2\pi r}$$

This is *Ampére's force law*.

Epilogue

The electromagnetic field is a dual entity always having an electric and a magnetic component ($\boldsymbol{E}$ and $\boldsymbol{B}$) simultaneously created by their common sources: moving charged particles. The substance of EM fields is e/b-information carried by informatons. In the article "*The Maxwell-Heaviside Equations Explained by the Theory of Informatons*" [5] it is shown that Maxwell's equations, *i.e.* the relations between $\boldsymbol{E}$ and $\boldsymbol{B}$, are the mathematical formulations of the macroscopic manifestations of the kinematics of the informatons. It turns out that there is no causal link between $\boldsymbol{E}$ and $\boldsymbol{B}$.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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