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A CONTEXT VISION

The electron: an analysis around its structure

El electrón: un análisis en torno a su estructura

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ABSTRACT

This paper presents an analysis around the ideas that emerged about the electron's structure starting from the original writings of Langeving, Lorentz and Poincaré, within the context of classical electrodynamics. Langevin seek an electromagnetic interpretation around of the inertia of the charged particles, while recognizing that such electromagnetic synthesis may be impossible. Lorentz, considered the mass of the electron of electromagnetic origin, constituted for inertial mass and electromagnetic mass, also evidence the need of inserting forces of nature different at the electromagnetic for counteract the effects of the electrostatic repulsion. Poincaré introduce besides of the electromagnetics actions, actions that prevent the disintegration the electron by effect of the repulsion electrostatic of the component parts. Sets together with the electric field, one force of nature mechanic for establish the unity the electron. This analysis allows us to contribute elements for the teaching of electromagnetics giving the possibility of develop a different teaching practice than the usual characterized for new schemes and levels of phenomenon explanations.

RESUMEN

Este artículo presenta un análisis alrededor de las ideas que surgieron sobre la estructura del electrón a partir de los escritos originales de Langevin, Lorentz y Poincaré dentro del contexto de la electrodinámica clásica. Langevin busca una interpretación electromagnética en torno a la inercia de las partículas cargadas, aunque reconoce que tal síntesis electromagnética puede ser imposible. Lorentz considera que la masa tiene un origen electromagnético constituido por una masa inercial y una masa electromagnética, además evidencia la necesidad de introducir fuerzas de una naturaleza diferente a la electromagnética para contrarrestar los efectos de la repulsión electrostática. Finalmente, Poincaré introduce además de las acciones electromagnéticas, acciones que impiden la desintegración del electrón por efecto de la repulsión electrostática de los elementos que lo componen. Establece conjuntamente con el campo eléctrico circundante, una fuerza de naturaleza mecánica para establecer la unidad del electrón. El abordar este tipo de análisis, permite aportar elementos para la enseñanza del electromagnetismo dando la posibilidad de desarrollar una práctica de enseñanza diferente a la usual, caracterizada por nuevos esquemas y niveles de explicación de los fenómenos.

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1. Problem context

In the last decade, there has been a great production and research proposals regarding the use and adaptation of new information technologies for the teaching of science and particularly physics.

In this sense, the development of ICT [1, 2] has enabled the production of computer equipment based on interactive applications that make it possible to visualize the concepts used in physics. However, they are not a reflection on the concepts, principles and theories of physics is done, because they assume as a center of education.

It is recognized that in teaching physical support of visual information for students looking for further understanding of the phenomena and concepts used in physics [3] is needed. This information is presented through diagrams, graphs, drawings or interactive applications that complement the exhibition of teachers and facilitate student learning. However, although these resources play an important role in the learning process of students, many times there are explicit that they are only models that teachers used to account for the phenomena, which causes students tend to attribute these didactic and representations to the realities of the physical world.

Furthermore, demand which is required for addressing new topics, it also raises a number of questions to teachers like these: How to promote the formation of scientific thought in students from physics is taught? How to express the process of knowledge of natural phenomena in the students? How to learn, and explanatory models and representations facilitate the teaching and learning of physics?

The reflection on the structure of the electron is not usually a topic raised in electromagnetism courses at university entry level [4]. Addressing this topic necessitates the creation of conditions that enable link students in the analysis and possible explanation of the structure of the electron with sense and meaning, which It allows opening a reflection on how relevant are the representative models for student learning.

2. The infinite in electrodynamics theory

During the eighteenth and of the nineteenth century thought possible to explain all phenomena based only on the laws of mechanics, since it was thought that a phenomenon was understood, given the recognition they have employment schemes and own models mechanical, if it could be explained in mechanical terms. Wherefore it came to understanding the mechanics and possible explanation for the phenomena [5].

To consider and apply the concepts that are the basis of mechanics, yet also adopt some of its representations, electromagnetic theory presents difficulties when you want to calculate the electric field intensity and energy of a point particle, since its value it tends to infinity. These results are inconsistent with the experimental evidence, since the observations do not show this kind of infinite. This issue was known to Maxwell as to reflect on the magnitude of the electric force exerted by the loading elements loaded on a point on the surface, comes to the following conclusion: "*it may be shown that a point charged with a finite quantity of electricity cannot exist in nature*" [6]. Thus, leaves open the problem of a possible structure of the electron.

3. The Langevin theory of electron

Recognizing the limitations embedded in Newtonian mechanics, Langevin assumed that the electromagnetic theory is the right to give explanation about the nature of the electron, since the difficulties in relating the concepts of mechanics and electromagnetism underlying the different ideas with respect to space and time. In this sense, it seeks an electromagnetic interpretation of the inertia of charged particles, while acknowledging that such electromagnetic synthesis may be impossible. Mass introduces three ways corresponding to all aspects of inertia. First, the mass and the coefficient of proportionality between force and acceleration. Second, as momentum capacity and third, as kinetic energy capacity [7]. From mechanics it is considered that there must be a match between the three definitions. Besides the invariance of mass for the same portion of matter regardless of changes of movement that is supported to experience.

The first definition suggests inertia as the property you have any material body. In the second definition introduces the momentum, whose variation in time is determined by the resultant force exerted on the portion of matter $dp = fdt$. Allowing define mass as momentum capacity, with the mass ratio between the momentum and velocity. The last definition comes from the concept of kinetic energy, defined as the total work to be done to carry a body from rest to a state of motion. Therefore, the mass is defined as the ability of kinetic energy, the ratio being twice the kinetic energy on the square of the speed with which the body moves.

To Langevin inertia is not a fundamental property of matter since the mass is a relativistic invariant. However, it considers that at low speeds v«c the three definitions should tend to the same value of the mass m_0; mass it is depending on the physical and chemical state of the particle and varies with energy exchange when interacting with the outside. This energy is supplied by external actions (forces) that print speed charged particle in the moment it is set in motion. The energy is then linked to the electron at its movement and is dissipated as work when it reaches the idle state.

The meaning Langevin gives the electromagnetic mass is the same meaning given to the inertial mass; as inertia ratio between the force applied to the electron and the acceleration experienced by this. Based on the experimental results of Rowland, and adopting the hypothesis of Abraham [8], [9], on the deformability of the electron, Langevin sees it as a sphere of radius (r), the distributed load surface the electric field established around it. In the words of Langevin "This brings her hair strength radial lines symmetrically arranged around" [7]. Finally, Langevin leaves open the issues surrounding the question of whether the inertia of the particle has a different origin than electromagnetic. Question which is subsequently taken up by the work of Lorentz and Poincare.

4. The Lorentz model

In his book problems of modern physics [10] shows that the Lorentz equation for a charged particle momentum $\frac{1}{c}\vec{E} \times \vec{B}$ It leads to the conclusion that its mass is electromagnetic origin. However, it argues that the equation is silent regarding the nature of the structure leaving open the problem of including a mass of different nature, "*therefore physicists are absolutely free to form any hypotheses on the properties and size of electrons that may best suit them*" [10], Looking hypothesis that best reproduce those observable properties of electrons and whose representations facilitate understanding the phenomenology observed. Lorentz is necessary for any explanation that is proposed for the structure of the electron must be general and can be validated by experiment.

Lorentz analysis considers the electron mass constituted by the inertial mass and an electromagnetic mass. Besides the need to introduce evidence forces a different electromagnetic to counteract the effects of electrostatic repulsion [11] nature. His conception of the electron is framed by wanting to understand how electric and magnetic properties depend on the temperature, density, chemical composition or crystalline state of the substance, "*We shall be obliged to have recourse to some hypothesis about the mechanism that is at the bottom of the phenomena*" [11]. Thus the electron Lorentz defined as: "*It is by this necessity, that one has been led to the conception of electrons, i.e. of extremely small particles, charged with electricity, which are present in immense numbers in all ponderable bodies, and by whose distribution and motions we endeavor to explain all electric and optical phenomena that are not confined to the free ether*" [11].

In its analysis, Lorentz considered the ether at rest and takes electrons as "Thinking of the particles of matter as of some Modifications in the home state of the ether" [11]; local conditions that may be considered as different ways of being the system. In this sense, the ether is no longer a simple representation of the actions a body burden can have on another to go to the description of the state space and its amendments; modifications, which are variations of the state, space near the bodies. Its aim is to establish a system of equations that describe the behavior allow the state space where there is an electrical charge from the idea of impregnating the ether in the electron, ie the electron is part of the ether.

Faced with the nature of the electric charge, Lorentz acknowledges that it is not enough to say that the charge density is a number belonging to a certain point in the ether. Distributed load considered in a given volume of space as a continuous function of the coordinates, assuming it as an amendment to the state of the ether to the point that it can consider the forces acting on them, producing or altering its movement, this being "*... the idea underlying the name of* "*charged particle*" *which we have already used and shall occasionally use again for electrons*" [11].

In their model, he proposes the electron with finite dimension and its interior consists of several volume elements whose interactions must vary from element to element. Stresses that one of the fundamental assumptions is to consider not only the ether fills the space between molecules, but also permeates inside the electron, being the means by which the internal interactions propagate. To permeate the ether inside the electron, it will exert a force on all internal points where there is the electron charge. This force will be determined by the state of existing ether within it. Also, when the electron is moving with a speed close to the speed of light, shape corresponds to an ellipsoid elongated in the direction perpendicular to its motion, and its charge will be described as a driver electrified with the same shape.

5. Experiments that served as support for the analysis of electromagnetic mass: Kaufmann experiments

In the early nineteenth century, it seeks to give an explanation for the observed phenomena from an electromagnetic context, being the objective of this worldview can explain the nature of the electron mass. Experimental support is framed in the analysis and determination of the charge to mass ratio of the particle. The experiments were based on the deflection experienced particles when posing as the action of applied electric and magnetic fields. These deflections were measured so that could be obtained the values of velocity v and e/m relationship.

When the range in particle velocities range from 0,5c to 0,9c e/m the value of the ratio decreased significantly, interpreted as an increase of the electron mass and the load is considered constant [12]. Kaufmann addition is that the force on the electrons depends on the velocity as:

$$eEf(\gamma) = eE\big(1 + \frac{\gamma^2}{2} + a_1\gamma^4 + \dots\big), \qquad (1)$$

Reducing the Lorentz force $\vec{F} = e\vec{E}$ when the speed of the electrons is small compared with the speed of light. Kaufmann [12], its analysis shows that the electrons have a mass given by:

$$m = m_0\big(1 + \frac{\gamma'^2}{2} + \dots\big) \qquad (2)$$

The result shows the dependence of the mass with velocity. Kaufmann using Langevin models and Lorentz obtained for the charge to mass ratio the following values:

- Langevin model (electron as a rigid sphere)

$$\frac{e}{m_0} = 1{,}955 \times 10^7 \qquad (3)$$

- Lorentz model (electron regarded as a constant volume variably)

$$\frac{e}{m_0} = 2{,}125 \times 10^7 \qquad (4)$$

From these values it is observed that the structural model of hard sphere Langevin, leads to greater mass than the Lorentz ellipsoidal model. Expected result since by varying the configuration of the fields on the ellipsoid, lower resistance to movement, a smaller moment of the electromagnetic field and therefore less electromagnetic mass occurs.

Finally, regarding Lorentz structure of matter says: "*I believe every physicist feels inclined to the view that all the forces exerted by one particle on another, all molecular actions and gravity itself, are transmitted in some way by the ether, so that the tension of a stretched rope and the elasticity of an iron bar must find their explanation in what goes on in the ether between the molecules. Therefore, since we can hardly admit that one and the same medium is capable of transmitting two or more actions by wholly different mechanisms, all forces may be regarded as connected more or less intimately with those which we study in electromagnetism.*" [11].

6. The Poincare model

Poincaré recognizes the difficulties of Lorentz's theory in relation to the structure of the electron. Highlight theory problem about stability as to consider it as a charged sphere electric forces act on itself leading to its disintegration. Therefore, also introduces electromagnetic actions, actions which prevent the disintegration of the electron effect of the electrostatic repulsion of the component elements. Faced with this problem, Poincaré proposes get strength from a potential $\varphi = \varphi(r, \theta)$ dependent on the axes of the ellipsoid of the form: $f = -\nabla\varphi$ [13]. This force is established together with the surrounding electric field counteracting the electrostatic repulsion and preventing its disintegration.

In their model, the unit provides electron considering the load on the field for something like rubber bands, [14] making these the charge remaining on the surface of the sphere. In order to determine this force, represented by a Poincaré the external pressure acting on the electron, proportional to the particle charge and interpreted as a self-action of the electromagnetic field on the particle that generates it. For Poincare it can be identified as a pressure acting inside the electron, as if each electron were hollow and subject to constant pressure and independent inertial volume. Force is the potential result of giving stability to electron and is commonly known as Poincaré pressure.

Poincaré presumably indicates that the electron motion and to all elements of the surface subjected to external pressure through the ether, as well as the effects of the electrostatic force and electromagnetic force due to the action of other elements, the balance of these forces on the electron it causes it to change becoming an oblate ellipsoid as proposed by Lorentz. Thus, the electrostatic force decreases at the poles and the pressure that comes from the ether Poincare, changes the shape of the electron accusing him to reach a new equilibrium. This pressure is what allows to understand the stability

Table 1: Comparative table on the structure of the electron.

Langevin Model	Lorentz model	Poincare model
Electromagnetic reductionism. Search for intrepreting electromagnetic inertia of charged particles. Inertia is not a fundamental property of matter as it is a function of speed. Assumes the structure of the electron as a deformable sphere of radius (r) with distribution of surface charge (e). The electron being electrified acquires an additional amount of energy of motion. Implying admitting localization of energy on the electric and magnetica fields surroundings the load. According Langevin electromagnetic mass is obtained as the mass inertia ratio. Langevin exposes the need for action to prevent disintegration of the electron effect of the electromagnetic repulsion between the volume elements that compose it. Attributing such actions to the action of the surrounding either on the electron. "The mass of a body ir equal to its total energy; the mass of a body measures its internal energy"(Langevin, 1956)	The electromagnetic momentum equation leads to think the total mass of an electron is electromagnetic in nature. Looking for a general theory that applies to places where there is space charge. He considers that not only either fills the space between molecules, but also permeates inside the electron, being the means by which the internal interactions propagate. Besides the corpuscular conception, an alternative design in which the charged as "local state changes either"particles are thought occurs. Loads should have a degree of substantiality and the distribution of volume charge. The gepmetry of the loda has an elongated elipsoidal shape in the direction perpendicular to their movement. Admitting the existence of (inertial) electron mass materials, which is one hundredth of electromagnetic mass, which gives substantiality necessary to atribute a form.	Existence of inertial mass of the electron materials, which is one hundredth of electromagnetic mass, which gives substantiality necessary to atribute a form. Focuses its analysis to determine the algebraic form and nature of the cohesive force. It represents the cohesive force by a constant external pressure acting on the deformable and compressible electron. The cohesive force is different from the electromagnetic source, and is responsible for ensuring the stability of the electron. Strength attribute to a proportional volumen of the electron (pressure Poincare) additional potential. This pressure can understand the stability of the electron as it is responsible for countering the effcets of the electrostatic repulsion of the different elements of the distribution of surface charge of the charged particle. The attempt to explain the nature of the mass in terms purely electromagnetic becomes an impasse, given the mathematical complexity theory acquires.

Source: own.

of the electron as it is responsible for counteracting the effects of electrostatic repulsion of the elements of the distribution of surface charge of the electron.

Considering the electron at rest and load distributed on the surface, electrostatic interactions between the various elements are balanced by the pressure from ether. In this way an image is obtained for the electron, however, the same Langevin says it is a provisional image and even provisional agreement with the experimental variation of the inertia of the electron with its velocity. Therefore considering the pressure it is justified as a key player for the balance and stability of the electron. Poincaré to introduce this additional force as new questions arise: What is the intensity of these tensions? What are balanced? And what are their properties? Questions that have no easy solution, since they depend on the assumptions that fall in the construction of an explanation, which could lead to a different image of a charged particle.

Furthermore, Poincaré recognizes that to calculate the electromagnetic electron mass is necessary to determine its total electromagnetic energy and the corresponding time. In this case, one cannot use the equations for the electromagnetic energy and time to distant points of the particle as it should treat the electron as a point structure. Therefore, considering the energy and momentum in parts located closest to the electron ether obtained by the time the field the expression:

$$P = \frac{2}{3}\frac{e^2}{ac^2}\frac{v}{\sqrt{1-\frac{v^2}{c^2}}} \tag{5}$$

It is showing how the electromagnetic mass increases with speed. Result known long before the theory of relativity but usually is taught as if it were one of its consequences. Interestingly, the result of the change in mass with velocity and the relationship between mass and energy of a particle was known long before the advent of the theory of relativity, because these relationships were obtained from reflection on the structure and description of the motion of a charged particle.

Finally, an analysis of the nature of the electron in purely electromagnetic terms brings a series of problems since his explanation becomes increasingly complex and understanding becomes more difficult. According to Feynman [14] does not know how to build a consistent theory that does not result in an infinite for the electron energy or any point charge, there is no satisfactory theory describing a non-point load, two problems still unsolved, Table 1.

7. Conclusion

- Building on the work by Langevin on the nature of the electron mass, shows that inertia is not a fundamental property of matter and in their various definitions, the mass and inertia coefficient, mass and impulse capacity and the mass and kinetic energy capacity, longer match when body speed approaches the speed of light.
- To Lorentz is necessary that any proposed theorizing about the structure of the electron, should lead to results showing that any object in the direction of its movement to contract. This idea is closely related to the development of the special theory of relativity. However, Lorentz not share the idea that the mass is completely electromagnetic proposes assume that the energy of an electron is not only electrostatic but also be constituted by a part of different nature.
- Poincaré enter bands called rubber or pressure Poincare to give explanation to the stability of the electron, as this pressure is responsible for countering the effects of electrostatic repulsion of the different elements of the distribution of surface charge of the particle charged.

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