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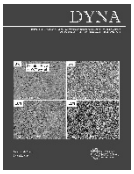

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The epistemological obstacle in Electromagnetism

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Abstract
In the development of a historical analysis on the natural phenomenon of electromagnetism, recurrently a question appears on the subject: why does it take researchers about 2300 years to decipher, understand and then dominate and apply the electromagnetic phenomenon for the benefit of the human being? To answer this question, the hypothesis about Bacon's "idols" and Bachelard's epistemological obstacle are presented. Both posed very correctly about the theory of knowledge: the limitations or impediments that affect the ability of individuals to build new knowledge. The fascinating interpretations, myths and legends, even the scientific understanding and its technological applications that changed life on earth, have been compiled and analyzed in this article, and in the Torres´s book [18]: *"The enigma of Electromagnetism under the magnifying glass".*

Keywords: electromagnetism; paradigm.

El obstáculo epistemológico en el electromagnetismo

Resumen
En el desarrollo de un análisis histórico sobre el fenómeno natural del electromagnetismo, recurrentemente aparece una pregunta sobre el tema: ¿por qué los investigadores tardaron cerca de 2300 años para descifrar, entender y luego dominar y aplicar el fenómeno electromagnético para beneficio del ser humano? Para responder esta pregunta se presenta la hipótesis sobre los "ídolos" de Bacon y el obstáculo epistemológico de Bachelard. Ambos plantearon muy acertadamente sobre la teoría del conocimiento: las limitaciones o impedimentos que afectan la capacidad de los individuos para construir un nuevo conocimiento. Las fascinantes interpretaciones, mitos y leyendas, hasta el entendimiento científico y sus aplicaciones tecnológicas que cambiaron la vida sobre la tierra, se han recopilado y analizado en este articulo y en el libro de Torres [18]: "El enigma del Electromagnetismo bajo la lupa"

Palabras clave: electromagnetismo; paradigma.

1. Introduction

The research process on the electromagnetic phenomenon of lightning has led me in the last 40 years to know, analyze, propose, test, and discuss the physical, mathematical models and results that have led to technological innovations and myths, legends, and scientific interpretations on the electromagnetic phenomenon in all cultures from the Acadia in Mesopotamia, the Egyptian, the Greek, the American Indians to the scientist in our days.

In this process I have learned that one of the characteristics of current science is that it cannot claim to achieve true knowledge, but rather obtain rigorous and verifiable knowledge, that is, with science we can only have the explanation of a natural phenomenon with temporary certainty. Science as such cannot claim an illusory goal that its answers are definitive.

Many historians, writers and scientists, such as Ahlbom [1] Kuhn [12], Torres [19], Berkson [4], Dietz [8], Darrigol [7], Harman [10], Navarro [14], Pickover [16], Johnk [11] have reported on the phenomenon of electromagnetism in books, articles, papers, and through their reading I am repeatedly asked a question on the subject: why did researchers take about 2300 years to decipher, understand and then dominate and apply the electromagnetic phenomenon in the daily life of the human being as in the electrical home appliances, the refrigerator, the blender, the vacuum cleaner, the microwave oven, the telephone, the electric motors and transformers, the transmission of wired

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or wireless electrical energy, or the new advances in mobility with electric cars or magnetic levitation trains, or in medicine with magnetic resonance imaging and in the trade with magnetic cards or digital storage on magnetic tapes?

From the first civilizations, the knowledge and explanation of the phenomena of nature such as light, rain, lightning, earthquakes, electricity, or electromagnetism, has made humans ask themselves questions of how ?, why? , when ?, where? and try to find an explanation, starting from a small number of basic principles and in different languages, such as mythical, up to what we know today as scientific: that process of appropriation, measurement, construction and autonomous creation of knowledge with visible, communicable, verifiable and socially valid results.

2. The paradigm of the four elements

In search of fundamental order and simplicity in nature, the Greeks Thales of Miletus, Heraclitus, Anaximenes, Xenophanes, and Aristotle, tried to describe all the matter of the universe, of the cosmos, using the paradigm of the four elements: Earth, Water, Air, and Fire, [18]. And this was how this paradigm lasted in all western cultures until at the end of the 19th-century science began to give explanations, with laboratory tests and mental models on the intrinsic constitution of matter, beyond the paradigm of the four elements.

The paradigm of the four elements was initially raised by the pre-Socratic philosophers and lasted in the Middle Ages until the Renaissance, deeply influencing European culture and thought. The states of matter, according to modern science and, to a lesser degree, also the periodic table of the elements, and the concept of combustion (fire) can be considered successors of that early paradigm.

Thales of Miletus stated that water is the beginning and particularity of all things in the cosmos, thus giving a first specific explanation of the physical world.

Anaximenes argued that air becomes other things through two new concepts: rarefaction and condensation. Rarefaction generates fire and condensation generates wind, clouds, water, earth, and stones; from these substances, the rest of the things are created. He considered the earth as a feminine, receptive, and nutritious element: Mother Earth.

Xenophanes determined the characteristics of the land as detachment and aridity.

Aristotle ratified the theory of the four roots of Empedocles (about 450 BC) and was the one who called them the four essential elements of the Earth.

These four elements were used by Hippocrates when he described the human body in relation to the four senses of humor: yellow bile (Fire), black bile or melancholy (Earth), blood (Air), and phlegm or mucus (Water).

3. The interpretation of the Electromagnetic phenomenon

The understanding of the phenomena of electricity and magnetism as they are known today began to appear in the time of the philosopher Thales of Miletus, 550 years before our era, with the discovery of some manifestations of matter.

One of them was magnetite (Fe_3O_4) which has magnetic properties in its natural state and owes its original name magnítis lithos (μαγνήτης λίθος), whose meaning is “stone of Magnesia”. From there the names of the words magnet and magnetism are derived. The names of the elements magnesium and manganese are also derived from the name of this region. Magnesia was one of the four Greek prefectures in which Thessaly was subdivided, a geographical-historical region of the Balkans that today belongs to Greece, on a large bay of the Aegean Sea, the Pagasetic Gulf or the Gulf of Volos.

More than 2100 years later, around 1650, when the Greeks raised the paradigm of the four elements, the German physicist and jurist Otto von Guericke [15] insisted on the paradigm of the four elements, rubbing spheres that contained materials that simulated the composition of the earth, without realizing that he had invented the first electrical machine.

Galileo, for example, considered the discussion of the work of the English philosopher and physician William Gilbert on magnetism good science. Gilbert, who observed that the magnetization of iron is lost when heated to red, studied the inclination of a magnetic needle, concluding that the Earth behaves like a great magnet. This was worth for Galileo to write [9]: *"I greatly praise, admire and envy that author for the many new and true achievements made by him, to the shame of many lying authors."*

At that time, what was written about magnets was useless tradition and absurd, if fun, superstition. An example of the traditional beliefs that Gilbert refuted, was that the magnet stone lost its attractive force in the presence of garlic, goat blood or diamonds, among others, showed that there was no effect in surrounding a magnet with 75 diamonds.

Gilbert's systematic work not only provided a solid basis for future research on magnetism, but also from his experiments he developed techniques for making permanent or "artificial" magnets for use in compasses.

Finding a new natural phenomenon such as magnetism, which did not fit into the paradigm of the four elements, the scholars of the mid-eighteenth century [12], insisted and proposed the first approach and defined the natural phenomenon as a *"subtle fluid"*, the *“electric fire”*, as a slight approach to one of the four elements: fire. Likewise, other scholars of the time insisted that the repulsion between two bodies as a secondary effect of a mechanical nature, under the influence of Newton's third law: If a body acts on another with a force (action), it reacts against that with another force of equal value and direction, but in the opposite direction (reaction).

In the middle of the 18th century, the American politician and inventor Benjamin Franklin, made a great contribution to the knowledge of the electromagnetic phenomenon when he proposed the principle of conservation of electric charge, despite the fact that this concept was not yet known in his time and only managed to call it *"electric fluid”*, something intrinsic to matter. Franklin proposed in 1749 an experiment: that of the *"sentry box"* or sentry box, in which a person standing on an isolated bench, holding a pointed steel rod extended vertically several meters, could attract the *"electric fire"* of a storm cloud that passes over, [20].

Only with the work of Franklin and his immediate followers did a theory emerge that could explain almost all of these effects, thus providing a paradigm for subsequent research. Franklin's theory assumed that a certain amount of a single fluid would determine the neutral state; an excess or defect would give electricity of a different kind. Pursuant to this assumption, he suggested calling electricity, which until then was called vitreous: positive, and resinous: negative.

4. The breakdown of the Greek paradigm

Later in 1789 the French biologist and chemist Lavoisier, with the *Elementary Treatise on Chemistry*, [13], led the consolidation of the chemical discipline and clarified the concept of an element as a simple substance that cannot be divided by any method of known chemical analysis and developed a theory of the formation of compounds from the elements.

Towards 1850, the understanding of electricity and magnetism was advanced by proposing a more reasonable, objective, measurable, communicable, verifiable and socially valid explanation, with the experiments and reasoning of Faraday, Ampere, Oersted and the four mathematical equations of Scottish scientist James C. Maxwell, as described by Torres [18], thus breaking the paradigm of the four elements.

And in 1897, about 2,300 years after the discovery of the magnet stone by Thales of Miletus, British physicist Nobel Prize winner Joseph J. Thomson discovers a new particle that was later dubbed the electron and breaks definitely the Greek paradigm, which later with the theory of relativity is advanced beyond Newton's laws and the intrinsic understanding of matter is achieved, the electromagnetic phenomenon is mastered and used in countless daily applications for the good of humanity, for example, Tesla, as Torres [21] describes it in his article *"Nikola Tesla, the man who invented himself in the 20th century."*

5. The first approach to an answer

Why did it take about 2300 years for the human being to decipher, understand, and then master and apply the electromagnetic phenomenon? There are surely many answers to this question since knowledge is a mental representation of objective reality and since it is dynamic, knowledge about a phenomenon of nature such as electromagnetism has to be adjusted, enriched, or eliminated to make way to another, that better explains objective reality. A process that has been carried out for more than 2400 years.

In order to enrich the discussion, it is pertinent to pose a hypothesis, as a first approach to answering that question.

On the theory of knowledge, the most important contributions were made by the French philosopher and physicist Gaston Bachelard [2] with the approach of the epistemological obstacle and the English philosopher, politician, and lawyer Francis Bacon with the approach of idols, [5]. Both found elements within the intellect that hinder the accurate knowledge of the real and do not allow the adequate evolution of the spirit so that it can pass from a pre-scientific state characterized by the objective, the immediate, given by the senses to a state scientific characterized by current physical sciences, [22].

Bacon in his book *Novum Organum* [5] deals with the logic of the technical-scientific procedure, a logic that is opposed to Aristotelian and that was good only for verbal dispute. It is necessary to get rid of the prejudices that hinder new ideas.

He called prejudices *idols*, which he classifies as common to mankind, which do not accurately reflect the nature of reality, and which subjugate understanding; that they come from baseless opinions guided by the senses; derived from each person's beliefs, a product of their education, habits, and customs; that they come from the abuse of language, where the force of the word is imposed on the thought generating disturbing ideas; that they come from false philosophical, theological and traditional systems that is nothing more than a fable staged.

A clear example of these idols that still remain today in the scene of primary and university education on the physics of electromagnetism is the explanation of *"poles of opposite signs attract and the same sign repel ."* This metaphorical explanation departs and does not contribute to the scientific explanation since attraction and repulsion are manifestations of human feelings and nature has no feelings.

The epistemological obstacle is not the technical difficulties of an investigative process, but, according to Bachelard [3], most of the obstacles are psychological and are in the mind of the investigator, in his preconceptions, in his prejudices, that must be overcome to advance objectively in the process of seeking knowledge.

Bachelard [3] identifies ten epistemological obstacles: early experience, the realistic, the verbal obstacle, the unitary and pragmatic knowledge, the substantial, the realistic, that of digestion, libido, and qualitative knowledge. The first three coincide with Bacon's *idols*.

The first that must be overcome is that of the first experience, made up of information that is perceived and lodged in the spirit, generally in the first years of intellectual life that could not be subjected to any criticism. In this obstacle lies the importance of early education on the phenomena of nature, which must be taught on a strictly scientific basis, with metaphors but explained scientifically, understandable, and pleasant to the student.

The second is the realistic obstacle, which consists in taking the notion of substance as a reality, which is not disputed and from which a whole series of knowledge starts, which has a direct and indisputable relationship with the nature of the substance itself, as is not it can explain it is taken as a fundamental cause or as a general synthesis of the natural phenomenon to which it is assigned. A real, mysterious substance, like the magnet or the stone of Magnesia, ceased to be a scientific problem to become the generator of all reality.

The third obstacle is the verbal one and it is located in the verbal habits used on a daily basis, which become more effective obstacles the greater their explanatory capacity.

Bachelard shows that epistemological obstacles appear not only in contemporary science but also in a very evident way in antiquity and in medieval times, which shows that they are not characteristic of a particular scientific

community or of a stage in the history of knowledge but they are present in the subjects who have tried to do science throughout all time; it is only through the systematic overcoming of epistemological obstacles that the spirit can evolve from a pre-scientific state in which the raw material of knowledge is the reality surrounding one in which the very notion of reality is taken as an excuse to make science, in which new knowledge emerges from new existing realities, sometimes only as mathematical symbols, [22].

Although neither Bachelard nor Bacon treat it, today, there is an additional epistemological obstacle, product of the advance in the knowledge of nature in so-called developed countries such as the USA, Europeans or Asians and very few contributions in the so-called emerging countries, in the process of development or the third world, in which the prejudice of those makes it difficult to recognize and advance new knowledge if they have not previously raised or published it [20]. For a third world researcher to be recognized worldwide, it is necessary to leave the country and work in a first world institution, [6].

Additionally, the visibility among research results in academic journals from developing countries (compared to developed countries) has certain characteristics such as: low international recognition of advances in research on topics specific to developing countries, editorial quality standards in magazines from developing countries are highly variable and the largest proportion of national production (even if it is of high quality) is published in national magazines [17].

6. Conclusions

In these ten epistemological obstacles raised by Bachelard and in the notion of *idols* that Bacon classifies as psychological prejudices common to mankind, that is, the limitations or impediments that affect the ability of individuals to build a new and revolutionary knowledge would be the answer of the slow advance in the knowledge of the electromagnetic phenomenon and its subsequent applications. And this could happen for about 2300 years and maybe happening now: the limitations imposed by previous paradigms, that is, that set of practices and knowledge that define the understanding of nature during a specific period of time.

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