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# Exploration of the Effect of Multiple Charges in the Teaching of Electrostatics

Jizreel Pereira da Silva[1]

[1] *Higher School of Education, International University Center, Paraná, 80020110, Brazil*
*Corresponding author. Email: jizreelsilva@yahoo.com.br*

**ABSTRACT**

*The paper presents the theme addressed in the classroom for students of the 3rd year of high school, in a public school in São Cristóvão, Rio de Janeiro, with the objective of extracting information through the exploration of the effects of multiple loads in the teaching of electrostatics. Two principles of electrostatics were addressed, such as load conservation and quantization of electrical load, being fundamental points for the experimental realization. The theoretical foundation was based on John Dewey is arguments, emphasizing the need for the use of experiments in science classes, conditioning the student to be the protagonist of the educational process, as well as that of Paulo Freire, so that students participate in the activities with critical and reflective posture, raising hypotheses and arguments necessary for the construction of their own knowledge. We initially discuss theoretically the fundamental aspects of the electrical charge, with the initial discoveries of the Greeks, traveling through scientists at various times in history, working on the development and improvement of electricity. We applied an experimental activity to explore and complement the exposed treatment on the interactions of electrical charges, with the division of two groups, so that students discuss with each other and work to support the assumption, according to the determinations of the questions of the virtual experiment. We discuss the results, dialoguing with the students the possibilities and facts determined by physics.*

**Keywords :** electric charge; electrostatics; experiment; teaching.



## I. INTRODUCTION

Developing materials for the teaching-learning process is not necessarily an easy task for the teacher, because in the case of the use of tools for experimentation (physical or virtual) it is important in addition to the knowledge of the subject to be addressed, the test on the part of the teacher to pay attention to the achievement of the objectives for the theme to be treated.

The work points to the experimental exploration of various charges, being part of the teaching of electrostatics, where despite having four basic principles such as: conservation of charge, quantization of charge, Coulomb's law, and principle of superposition, we use in this proposal only the first two principles.

The work was applied with 22 students from a class of the 3rd year of High School, in a public school in São Cristóvão, Rio de Janeiro, with the main objective of encouraging experimental use to complement the classes particularly of Physics. For the nominal effect of the students, they will be called *A*, *B*, ..., *V*.

Physics, Chemistry and Biology (natural sciences) classes are essential for students to develop scientific thinking about the phenomena of nature. Therefore, it is important that the teacher uses methodologies, such as teaching by investigation, teaching by research, experimental work and even the use of games, because it puts the student in an active position in the educational process, making them feel part of this process.

It is known that there is a schedule of the lesson plan, but the teacher has the freedom to use these resources at some point in the didactic course to not only enrich in the construction process but motivate students to act and interact with the theme in question.

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Within this perspective, we follow the idea of John Dewey (1859-1952) where he emphasized the importance of experimentation in scientific activities, because science teaching was too expository, without the action of students, because he discussed that:

> [...] they were concerned with social institutions, especially the school, which did not follow the changes that occurred in the United States with economic development based only on capitalist interests in the early twentieth century. He wanted to reconstruct the conception of current knowledge by integrating it with the objects of science, calling this integration experience. In this way, what is important for human life now becomes important for science [1].

## II. THEORETICAL FUNDATION

It is important to emphasize that the world goes through transformations and consequently the school receives this need to adapt to the social reality we face.

It is necessary that the teacher puts the students in a position where they feel part of the process, where they come to elaborate conclusions, hypothesis survey, critical and reflective sense, because:

> It is necessary a transformation in the focus of teaching-learning situations, since the teacher and the school must have as main objective the formation of critical and reflective subjects, being necessary, therefore, changes in pedagogical practices. The change to which we refer is not only of curriculum, but in the relationships that occur in the school environment, which should promote a reflective, questioning, and recognizable education in the face of social development [2].

The teacher is gradually configuring himself to become a mediator of knowledge and condition students for an important role in the construction of the learning process, through this, it is important for the teacher:

> [...] to know that teaching is not to transfer knowledge, but to create the possibilities for its own production or its construction. When I enter a classroom, I must be being open to questions, to curiosity, to students' questions, to their inhibitions; a critical and inquiring being, restless in the face of the task I have [3].

This mediation takes place with the subject that is being taught and the student, with the use of various resources and the mediation takes place by the interaction to reach a level of knowledge, with production in the case of this work, by experimentation with the use of virtual simulators, but in all the theoretical discussion of the theme addressed, develop problems that:

> [...] When the teacher asks questions, he gives feedback to the students about their placements and productions, problematizes the content, with the objective of putting the student's thought in motion and, also, when he stimulates the students to dialogue with each other about their activities. As teaching comes to be understood as a process of mediation, the teacher ceases to be the center of the process to become a bridge between the student and knowledge. Thus, the usual questions of the teacher, such as: "what should I teach?", "How will I be able to teach all the contents?", are replaced by: "what are the priority contents in terms of students' understanding?", "How do I know if they are understanding these contents?", "What are the students' expectations regarding the classes and the discipline as a whole?" [4].

For Dewey the teaching of science is emphasized by expository and theoretical formalism, not leading the student to understand science as fundamental for social transformation, improvement in the quality of life, as well as the incentive of the student to be able to think and reflect. It also highlights that students should be active thinkers, not just memorize the content transmitted by the teacher, without using reasoning [5].

The proposed theme involves an active methodology on electric charge for students to act to complement learning with more consistency.

### *A. Electric Charges*

We use several devices, such as computer, cell phone, notebook, television, among others that require electricity, where there is the physics of electromagnetism. We observe even in the phenomena of nature, such as lightning and solar energy.

The physics of electromagnetism was first studied by the philosophers of ancient Greece, through the friction of a piece of amber (fossil resin with hues ranging from yellow to brown, widely used in the making of ornamental objects) [6] with subsequent approximation with pieces of straw, perceiving the attraction of these. And this attraction is now known as the electric force [7].

**Fig. 1.** Amber, a resinous material, was formerly used to manufacture various objects [8].

In the sixteenth century, William Gilbert (1544-1603), made studies of electromagnetism and concluded that the natures of a magnet and amber are different, as well as other substances were electrified when being rubbed, such as glass, wool, ebonite, leather, etc. These materials were called electrical materials, with reference to the amber stone that in the Greek is called *elektron*, and that the compass was oriented due to the magnetism of the Earth [8].

Through the development of scientists by discoveries and curiosities, they were worked independently and Michael Faraday (1791-1867), performed several experiments of electricity and despite having several laboratory notes, did not have calculations, possessing talent for intuition and visualization of physical phenomena. As in all scientific development there is therefore someone with the ability to improve and innovate, James Clerk Maxwell (1831-1879), mathematized the works of Faraday, also introducing his own ideas, giving consistency to electromagnetism.

Following the works in the wake of electromagnetism, the observation of certain phenomena such as the production of a spark when walking on some types of carpets and subsequent approximation of the hands to a doorknob, faucet, in dry weather, as well as the emergence of sparks in the removal of clothes from a dryer, this is due to the electrostatic attraction, where through these phenomena, we perceive the existence of electric charges in any object, being the electric charge intrinsic property of the fundamental particles, that is, it is a property associated with the very existence of the particles.

The electric charges are positive and negative, the equilibrium occurring if there is an amount of positive charge equal to the negative charge. In this case, the object is electrically neutral, with total charge equal to zero. For the case of charge signal difference, the total charge is nonzero, and the object is electrically charged [7].

In all these important works of static electricity, in fact, in practice they had no application outside the laboratories and the great impulse took place around 1800 with the invention of the pile by Alessandro Volta (1745-1827), Italian researcher, found that when stacking alternating discs of zinc and copper, separated by wet paper with salt water, adding two wires to the terminals of his pile, he noticed that when he touched the two ends, a spark came out, concluding that electricity ran on the wires, calling it electric current [8].

The electric charge consists of two properties, being the electric charge itself and the charge-carrying particle. In the first property, it considers the dicussion that the amount of electric charge of a body is quantized and there is the conservation of these charges, by the non-observation of creation and annihilation of electric charge.

In the case of particles carrying electric charges are electrically charged particles, such as metals, where the carriers of negative charge are the electrons, in fluids the carriers of positive charges are the cations, because these ions have protons in excess [9].

All things are made up of molecules and these molecules of atoms. The basic composition of atoms is given by protons, electrons and neutrons. Protons have a positive charge, neutrons are formed by a proton and an electron, totaling zero for their charge and protons with a positive charge.

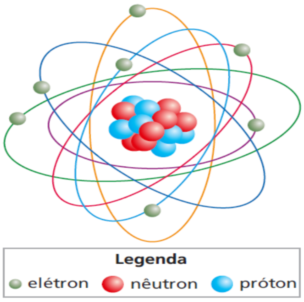

**Fig. 2.** Atomic model [8].

When there is a lack of electrons in a body, we say that it is positively electrified and when there is an excess of electrons, it is negatively electrified. In a body, the removal or addition of electric charge will always be electrons, in view of the electron being further away from the nucleus of the atom, being this nucleus composed of the proton and neutron, so it facilitates the transfer from one body to another, because to remove the proton, there is a complicated work in practice.

All this study is related to electrostatics that studies the physical phenomena produced by electric charges at rest and to electrodynamics that studies the effects of electric charges in motion and one of the basic principles of electrostatics that deals with the behavior of electric charges when they interact with each other is that of electric charges of the same signal repel each other and contrary signals attract, being a consequence of the field or force lines around an electric charge, this principle is known as the principle of attraction and repulsion [10].

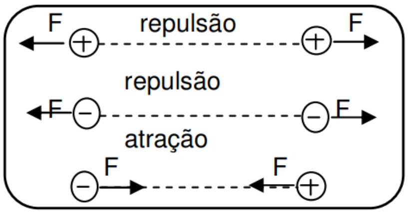

**Fig. 3.** Repulsion of electric charges of the same signal and attraction of charges of contrary signals [10].

For the case of the principle of conservation of electric charges is when in an electrically isolated system, the algebraic sum of the quantities of positive and negative charges is constant, for example, two bodies *A* and *B* with amounts of electric charges $Q_1$ and $Q_2$, considering that there was the exchange of charges between the bodies, and are, respectively $Q_1'$ and $Q_2'$ the new quantities of charges of *A* and *B* [6].

Through the principle of conservation of electric charges, the total amount of electric charge after the exchange is equal to the total amount of initial electric charge, being expressed in the form:

$$Q_1 + Q_2 = Q_1' + Q_2' \quad (1)$$

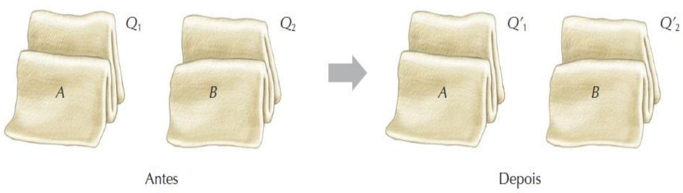

**Fig. 4.** Bodies *A* and *B* are electrified with amounts of charges $Q_1$ and $Q_2$. After the exchange of charges between the bodies, the new amounts of charges will be $Q_1'$ and $Q_2'$ [6].

When dealing with the International System of Units (SI), the unit of electric charge is the coulomb, symbol with C (capital), in honor of the physicist Charles Augustin de Coulomb (1736-1806). Although the unit of electric charge is not the base of the (SI), but through the experiments it was possible to determine the value of elementary charge for $e = 1.602.10^{-19}$ *C*. The amount of electricity or electric charge will always be a multiple of the elementary charge:

$$Q = \pm ne \quad (2)$$

Let *n* be a natural number. This integer property shows that the electric charge is a quantized quantity. In 1923, Robert Millikan (1868-1953) received the Nobel Prize in Physics for experimentally determining that electric charge was always a multiple of the value $e = 1{,}602.10^{-19}\ C$ [8].

## III. METHOD

The proposal of the work was to develop the theme on electric charges, with part of theoretical discussion and experimental part with the use of virtual simulator. The study was applied to 22 students of the 3rd year of high school, in a public school in São Cristóvão, Rio de Janeiro, Brazil.

We approached the activities in two meetings, the first meeting with the subject of electric charge, where we used the frame to expose the calculations and slide projection of the images, discussed according to section 3 of this work.

In the second meeting, an experimental activity was carried out in two groups: Alpha and Beta, composed of 11 students each. The experimental procedure takes place through the simulator Physlet Physics 3rd edition, with challenging problems authored by Christian and Belloni [11].

Initially a pink test load with the letter *t* positive is shown in the simulator. The student will be able to add positive and/or negative charges, with all charges added in the middle of the simulation, and the student must drag each newly added load to a new location. By pressing "play", the test load will move under the influence of the forces of the other loads, showing in the system the duration of the event.

Each group receives a sheet containing three questions for the experiment, for notes of the results obtained. All proposals are identical for the groups. The experimental questions follow below:

1. Add a positive charge. Describe and explain the movement of the test load.
2. What is your prediction for the movement of the test charge if the positive charge is replaced by a negative charge?
3. Set up two loads of the same signal so that the test load remains stationary. Describe your configuration.

## IV. RESULTS AND DISCUSSION

The two groups had a lot of interaction, with dialogues, discussions and controversies which is to be expected from group work.

For the 1st question, the groups answered similarly, because they considered according to the statement the addition of a positive particle and as the test charge is positive, they realized that when approaching this positive charge to the test charge, there was a departure from the test load, as expected.

At the time of delivery of the reports and discussion with the students, student K, stated that: "*teacher it is impossible to make the test load come to touch the positive charge*!" I asked what support was given for the charge not to touch in this case, and she found it interesting, because she agreed with the study, that particles of equal signals would repel each other.

Student *E* asked, "*Professor, is the charge of the electron always negative*?" The answer was yes, given that science to this day has failed to verify the controversy. All particles have a specific configuration, for example, the proton, will always have a positive charge.

In the 2nd question, all groups as expected, answered that in the substitution of the positive charge for the negative one, there would approximate the test load until its collision and in the 3rd question, only the alpha group was able to configure, but with several attempts and realized that the ideal position is in the middle of the two loads. The beta group found it difficult to configure both payloads of the same signal.

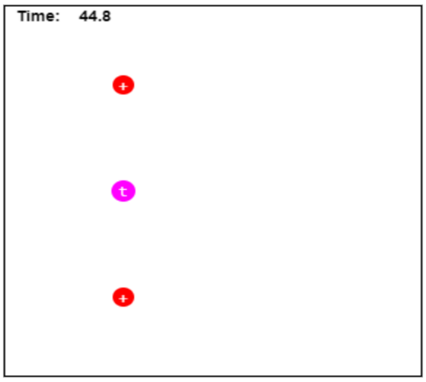


**Fig. 5.** Configuration of the alpha group for stabilization for stationary test load [11].

The groups worked to solve the items in question, although the beta group failed in stabilizing the test load. Student *I* of the beta group, argued that: "*teacher, we can not put the charges because we put between two negative charges!*". Another student *L* of the alpha group made the following comment, interesting that: "*placing the test charge in the middle between two charges of the same signal, this test charge will stand still, because in your case, the negative charge would pull to one side and the other to the other side, resulting in stability*".

Certainly, they could not configure the test load in the medium itself and the students realized in this simple simulation, about the relationship of particles with positive and negative charges, where depending on the type of configuration of the system, a certain behavior for the test load will be observed.

## V. CONCLUSION

The students performed satisfactorily the activities in relation to the study of electric charges, because during our theoretical discussion, they raised their questions about charged particles and even questions about the magnet, aspects that involve magnetism, which would be outside the topic addressed.

The proposal of the work aimed to condition the students in a posture similar to that of a researcher, developing critical sense, reflection on the proposed theme, initiative, cooperation among colleagues in the group, ability to alternate models to achieve the goal, raise hypotheses and questions, even if out of scope, but that will bring great benefits and enrichment in learning, Because in any case, the teacher at an opportune time, will bring answers or develop questions for the next works in the classroom.

It is perceived that the activities that make the student become participatory, facilitate in the didactic treatment of the teacher, and help in the effectiveness of the educational process.

In a simple language about the educational process is that if the a priori mission of the teacher is to teach and the student to learn, certainly with the use of methodologies of this type, they will bring benefits not only to the student, but to the teacher as well.

The students in general noticed the functioning of the interactions of charged particles and demonstrated satisfaction in carrying out the virtual experiment.

Increasingly teaching Physics becomes a challenge for the teacher and when designing activities that in the end will guarantee the goal, certainly make the learning of students significant and demonstrates that all the effort of the teacher is valid for the consolidation of what is expected in the didactic actions.

## REFERENCES

[1] F. A. C. Vieira. *Teaching by research and critical meaningful learning: phenomenological analysis of the potential of a teaching proposal*. Doctoral Thesis, Faculty of Sciences, University of São Paulo, Brazil, 2012.

[2] V. L. Milk. *The study of the various forms of energy production in a CTSA approach: seeking evidence of scientific literacy of high school students*. Master's degree in physics teaching, Federal University of Espírito Santo, Vitória, Brazil, 2015.

[3] P. Freire. *Pedagogy of autonomy: knowledge necessary for educational practice*. 43rd ed. São Paulo, Brazil: Peace and Earth, 2011.

[4] B. G. Nadal and S. Papi. *The work of teaching: contemporary challenges*. In: B. G. Nadal. (Org.). Pedagogical practices in the early years: conception and action. Ponta Grossa, Brazil, 2007.

[5] B. A. Rodrigues and A. T. Borges. *Science teaching by research: a historical reconstruction*. Proceedings of the XI Meeting of Research in Physics Teaching. Curitiba, Brazil, 2008.

[6] J. F. Ramalho, G. F. Nicolau and P. A. Toledo. *The Foundations of Physics, vol 3. Electricity, introduction to modern physics and dimensional analysis*. 10th ed. São Paulo, Brazil: Moderna, 2009.

[7] D. Halliday, R. Resnick and J. Walker. *Fundamentals of Physics, Volume 3: Electromagnetism*. Translation and technical revision BIASI, R. S. 8th edition, Rio de Janeiro, Brazil: LTC, 2009. 4v.

[8] C. S. Sidewalk and J. L. Sampaio. *Classical physics, 3: electricity and modern physics*. 1st ed. São Paulo, Brazil: Actual, 2012.

[9] C. O. Grace. *Lesson 1_1: electric charge*. Short Distance Learning Program, Course of Mechanical Engineering, General and Experimental Physics III, Department of Physics, University of Santa Maria, Santa Maria, Brazil, 2012. Available: http://coral.ufsm.br/cograca/graca1_1.pdf.

[10] R. Wykrota. *Electricity*. Physics handout. Part 2. Notes 82, 83 and 84. State Center for Professional Education of Curitiba, Curitiba, Brazil, 2023. Available: http://www.ceepcuritiba.com.br/arquivos/Professores/Ronald%20Wykrota/Fisica/APOSTILA%20FISICA%20parte%202%20CEEP.pdf.

[11] W. Christian and M. Belloni. *Exploration 22.2: explore the effect of multiple charges*. Physlet Physics 3rd Ed. Northfield: Compadre, 2013. Available: https://www.compadre.org/Physlets/electromagnetism/ex22_2.cfm.