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Analysis of a questionnaire on the photoelectric effect in high school

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Abstract: *The work shows an analysis of an application of a questionnaire about the photoelectric effect to a class of the 3rd year of high school, where the study was approached with student interaction, developing works to understand the potential necessary to remove electrons from the metal through the radiation of incident photons, within the specificity of the material studied.*

Keywords: effect; photoelectric; energy; light.

1. INTRODUCTION

Modern and contemporary physics is still a sensitive topic for teachers to discuss in the classroom. For various reasons, each professor will have their own argument to apply themes of this nature, where most are limited to working with topics of classical physics, because they believe it to be more coherent and more realistic.

The problem is that the world is updated, and most students have contact with technologies and the school is automatically pressured to adapt to the reality of the society in which the students are inserted.

The theme on the photoelectric effect introduces students to this journey towards modern and contemporary physics, where it brings the contact closer to the understanding of new technologies and interesting effects on people's daily lives.

In this work, we will briefly address the photoelectric effect, the methodology and the procedure adopted in the classroom and an analysis of the results of the questionnaire applied to students of the 3rd year of high school.

2. THE PHOTOELECTRIC EFFECT

No final do século XIX e início do século XX, novos fenômenos físicos foram descobertos e surge a necessidade de novas ferramentas para explicar os novos fenômenos até então tidos como definitivo, originando a Física Quântica.

Realizaram diversos experimentos e trabalhos para encontrar uma lei que relacionasse a temperatura e o comprimento de onda com a quantidade de energia irradiada pelos corpos aquecidos.

Max Planck (1858-1947) tinha o objetivo de resolver um problema da emissão de radiação pelo corpo negro, não obtendo êxito, pois os cálculos levaram a resultados incoerentes, ficando conhecidos como "catástrofe ultravioleta".

Planck continued to devote himself to the study of thermal radiation, optics and thermodynamics and formulated the theory of quanta in 1900 [1].

Fig 1. *Max Planck (1901)* [2].

Planck came up with the idea of treating energy in a discretized way, as he believed that energy was transmitted in specific quantities, such as in energy packets. Planck called quanta (plural of quantum) of energy, giving rise to quantum theory. Therefore, energy is transmitted discontinuously, that is, quantized.

The first uses of Planck's hypothesis of energy quantization appeared in Einstein's two papers, one in 1905 on the quantization of radiation itself and the other in 1907 on the specific heats of solids. For this discovery of energy quantization, Planck was awarded the Nobel Prize in Physics in 1918 [3].

Planck, to explain the nature of the electromagnetic radiation emitted by the surface of a black body, considered that: "*An electron, oscillating with frequency f, emits (or absorbs) an electromagnetic wave of equal frequency, but the energy is not emitted (or absorbed) continuously*".[1]

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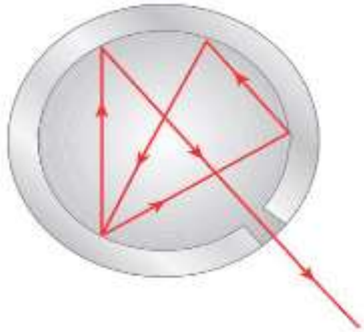

Fig 2. *A practical model of a blackbody consists of a hollow object with a small hole. The hollow object is heated by means of a heat source, situated inside. Through the hole there is the emission of radiation by heating. Any radiation incident to the hole will be absorbed by the inner walls of the hollow object. Thus, the orifice will emit and absorb as a black body* [1].

Planck considered that radiant energy is not emitted or absorbed continuously, but in particles that each carry a well-defined amount of energy *E*, these particles are called photons. [1]

Photon is the elementary particle that mediates the electromagnetic force. The photon is the quantum of electromagnetic radiation (including light), which is the Greek word for light.

According to his formulation, the *energy E* of the quantum "packet" is given by the product of a constant *h*, known as Planck's constant, whose value is $6.63.10^{-34}$ *Js* (Joule-second) or $4.136.10^{-15}$ *eVs* (electron-volt-second). By the frequency of the radiation *f*, we have

$$E = hf$$
$$hf = E_f - E_i \quad (1)$$

Only integer multiples of *hf* will be allowed, with *n* being the quantum number, as the energy is quantized [4]. So

$$E = nhf \text{ with } n = 1, 2, 3, 4\ldots \quad (2)$$

When electromagnetic radiation falls on the surface of a metal, electrons can be stripped from that surface. This phenomenon is called the photoelectric effect. The electrons stripped away are called photoelectrons.

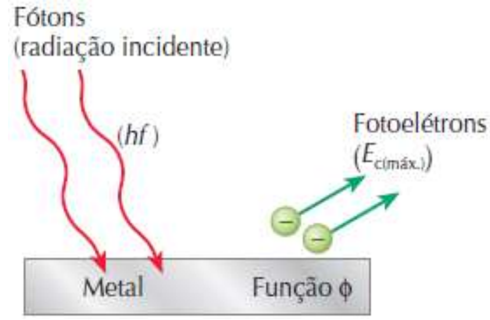

Fig 3. *The Photoelectric Effect* [1].

Albert Einstein (1879-1955) develops a theory considering the quantization of energy, but for the electron to escape from the metal it is necessary that it has a minimum amount of energy to overcome the collisions of neighboring atoms and the electrical attraction of the nucleus of these atoms. This minimum energy corresponds to φ work, called the metal work function. We must,

$$hf = \varphi + E(max) \quad (3)$$

Known as Einstein's photoelectric equation, where the energy of the incident photon is equal to the sum of the work function and the kinetic energy. In other words, when the electron receives the additional energy (*hf*) from the incident photon, this must be sufficient to overcome the *metal's* φ work function so that the electron can escape, where the excess energy is conserved by the electron in the form of kinetic energy. [1]

According to Einstein: "*the quantization of energy used by Planck in the black-body problem was, in fact, a universal characteristic of light*". [5]

The photoelectric effect is the ejection of a material when it is illuminated by a light source. The kinetic energy of photoelectrons does not depend on the intensity of the incident light, but on its frequency [6].

3. METHODOLOGY

The project on the photoelectric effect was applied to a class of 23 students from the 3rd year of high school in a public school in São Cristóvão, RJ, being identified from *A* to *W*. The project's activities lasted two days. The first day presented and interacted with the students the theoretical aspects of the photoelectric effect and on the second day, ending the discussion and introducing a questionnaire with three questions.

The classes were in the format of a slide (data show projection) and the use of a whiteboard to calculate the questions and examples of the discussions. The students were excited about the subject and the interaction was fruitful, as there were several questions during the discussion of the subjects.

Initially, we talked about the proposal of the works, that together we would be as researchers, as scientists, and that we would have problems to solve.

At first, the students were worried, because in addition to starting with a new treatment in the study, they thought they would have to solve everything individually. But it was clarified that scientists work as a team, in groups, and our work would be no different. After this understanding, a calmer posture of the students was noticed, as they would have colleagues with each other in the work.

Within this proposal, we perceive motivation to continue, even showing a certain fear for the activities, which is natural, as a kind of fear of making a mistake or asking something out of scope.

The difficulty that the students pointed out was in the purpose of the metalwork function. They understood the possibility of ripping electrons out of a metal, but the question was to what extent this would be possible for energy.

It was in the next class that they understood that each metal has its cutting potential, being essential to know the possibility of pulling electrons from the surface with a certain energy [7].

The questions of the exercise the questionnaire fixation exercise, through a questionnaire with three questions, was given as follows.

1. What is photoelectric effect?

2. The working function of zinc is 4.3 *eV*. A zinc photoelectron is emitted with a maximum kinetic energy of 4.2 *eV*. What is the energy of the incident photon that emitted that photon?

3. If light falls on hydrogen gas, it is possible that the atom, in its ground state $E = -13.6$ *eV*, absorbs a certain amount of energy and passes to the next permissible state (excited state). The energy required for this transition is:

(A) 9,97 *eV* (B) 10,06 *eV* (C) 10,20 *eV* (D) 10,59 *eV* (E) 10,75 *eV*

4. Analysis and Discussion of Results

The first question asks what the photoelectric effect is, with an open answer and the student answers according to his/her understanding.

Some examples of quotes from the students, responding that: *"It is when we use an incident radiation needed on some metal to emit photoelectrons". (F). "For the photoelectric effect to occur, there must be radiation on an iron metal." (W). "It is the ejection of a material when it is a light source and when we use a radiating radiation necessary to emit the photoelectron." (K). "It's an energy that goes through the metal and goes to the function that generates all of this." (B). "It is the effect that removes electrons from metals, such as iron, copper, etc." (Q).*

Approximately 38% had difficulty answering this question clearly, which is natural. The students had engagement, discussions together with the teacher, because the objective is to analyze the student's speech, respecting his way of exposing what he understands.

Those who answered "closer to expected" achieved the goal and analyzing their answers, there is a perception on the part of the student that the material to be applied must be a metal, such as iron, copper, aluminum, because wood and other types of insulating material, this effect would not work.

They also realized that for the emission of photoelectrons it is necessary to have light on the metal and that each metal will have a specific work function, that is, that each type of metal will require a minimum energy necessary for the emission of photoelectrons.

The second question asks the student to calculate the energy of the incident photon for the emission of photoelectrons with a kinetic energy of 4.2 *eV*, knowing that the working function of zinc was *4.3* eV. Even though the question was seemingly easy, 19% could not get the question right. Some, instead of adding up, made the difference in the values, perhaps due to the mistake in the positioning of the energies in the equation.

The third question asks the student to calculate the transition energy of hydrogen gas, i.e., the atom being in the ground state, after absorbing a certain amount of energy to move to the next permitted excited state. The question is multiple choice and 15% got this question wrong. The interaction of the students with the teacher and the search for the development of the activities reduce the uncertainties because we know the difficulties with the tools and mathematical manipulation of the students.

5. Final Thoughts

The theme about the photoelectric effect aroused the curiosity of the students, making them understand mainly by the ability to analyze the initial conditions of the problem, such as the type of material for the potential necessary to realize the effect itself.

Obviously, each student will have their own time to understand, because practice improves the activities, but when we approach students in an accessible language, interacting and making them think, respecting the individual way, we will certainly be objectifying the work of Physics, particularly modern and contemporary physics in high school.

The photoelectric effect motivated the students to desire more in-depth knowledge of physics, but it is crucial for the teacher to provide clarity and involvement of the topics and expanding the discussion with theoretical and simulation activities, as it will certainly make the student arouse more and more curiosity for physics.

6. References

[1] Ramalho, J. F., Nicolau, G. F., & Toledo, S. P. A. (2009). Physics 3: The Fundamentals of Physics, 10ª ed. São Paulo: Moderna.

[2] Planck's constant. (2023). In: Wikipedia, The Free Encyclopedia. Flórida: Wikimedia Foundation. https://pt.wikipedia.org/w/index.php?title=Constante_de_Planck&oldid=60274216.

[3] Caruso, F., & Oguri, V. (2006). Modern Physics, Classical Origins, and Quantum Foundations. Rio de Janeiro: Elsevier.

[4] Oliveira, O. A., & Fernandes, J. D. G. (2006). Atomic and molecular architecture. Rio Grande do Norte: EDUFRN.

[5] Tipler, P. A., & Llewellyn, R. A. (2017). Modern Physics, 6ª ed. Rio de Janeiro: LTC.

[6] Kaneko, U. F. (2017). Modern and Contemporary Physics. Paraná: Editora e Distribuidora Educacional S.A.

[7] Silva, Jizreel. P. (2022). Study of space-time quantization applied to the entropy of black holes. Rio de Janeiro: Dissertação, Departamento de Física, Universidade Federal do Estado do Rio de Janeiro.