Weightlessness vs. absence of gravity. An illustration of a didactic approach showing accuracy and attention to fact

J. Vila[1] and C. J. Sierra[2]
[1]*University of the Basque Country, Spain*
[2]*"Los Peñascales" Secondary School, Madrid, Spain*

E-mail: jesusvila@hotmail.com

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Abstract

Earth force and weight force are two of the magnitudes that are most used in mechanics and in our daily life. These two terms are commonly confused or taken as the same and this may lead to erroneous conclusions, as for example in relation to weightlessness. The following paper is a didactic approach that explains these concepts with great precision on the basis of their respective interaction and the three laws of Newton in relation to mechanical movement. It has been used with teachers and with groups of students, and very good results has been obtained.

Keywords: Weight and the frequent confusion to the term gravitational force, weightlessness**,** absence of gravity.

Resumen

Fuerza gravitatoria y fuerza peso son dos de las magnitudes más usadas en mecánica y en la vida diaria. Estos dos términos son generalmente confundidos o tomados como el mismo, y esto puede llevarnos a conclusiones erróneas como por ejemplo con la impesantez. El siguiente artículo es una aproximación didáctica para explicar estos conceptos con gran precisión en base a su respectiva interacción y la tercera ley de Newton en relación con el movimiento mecánico. Esto ha sido usado con profesores y con grupos de estudiantes, obteniéndose muy buenos resultados.

Palabras clave: Peso y la frecuente confusión con el término fuerza gravitacional, impesantez, ingravidez.

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I. INTRODUCTION

The accuracy of the concept 'weight' of an object and the frequent confusion that exists in relation to the term 'gravitational force' or simply 'earth force' is of great interest from a theoretical and pedagogical viewpoint.

The fact that, in systems of inertia, the numerical value of these two forces coincides can be considered an excuse, but it is still a conceptual error which should be eradicated in modern teaching.

Normally, we hear, read and even receive explanation, about, for instance, that an astronaut realised work in his ship to study the influence of the absence of gravity (on micro-gravity) in so on to experiment [4, 10]. It does not matter which, a newspaper, cultural television program, a technical magazine. Even in test books in all this items we find this kind of affirmation. Speaking of absence of gravity when we are facing the contradiction of long distances inferior at 400 km. From our planet, this in astronomical terms means "just across the street". Anyone can check, for that distance, is the acceleration gravity g = 8.7 m/s^2. If you put in account that Earth surface is g = 9.8 m/s^2, why 8.7 m/s^2 suppose to speak of "absence of gravity" on "microgravity"? [4].

Is unbelievable that the beginning of XXI century, with the extraordinary exit of the scientific work the idea of absence of gravity is still being used, for this matter the necessity of using several kind of tricks such as, apparent weigh, oven-weigh, and other frivolities trying to explain what happen in and elevator, on during "a hole" in a flying trip, in a "Russian mountain" and in others gravity attraction. We believe for all this reasons that is very important to explain to you the real difference between absence of gravity and weightlessness [6, 8].

We propose to study two faces of the matter: in the first place we must try you clean the point of what try knowing of the weigh of a body. The concept of a weigh of a body is very imprecise, even for the teaching. We used it normally as a synonymous of mass, "I weigh 80 kg"; and some other time as a measurement of volume "pour 25 cm^3 more of water weigh". This is totally considered the name or equivalent (in quality and quantity) at the gravity force and/on at the property of each body in itself. In several occasions it is used with "density". In consequence and in the first place, we are to define what wigh are [7]. In second place, we are to realise a very simple experiment with a soda – can and elastic band and some water. We can sea affect the items (springs, rubber band and containers). How even, it exist the planetary interaction. Between the previous ideas during the experiment, it is necessary to invent some forces (not produced for interactions) or to confuse the weight with that of the gravity. But the proper nature of the forces never is coincidental: the “weigh-force” is elastic, while the gravity-force is gravitational. And it is know that this force can not be shadowed.

II. METHOD

As a starting point, let us recall the definitions of these two forces. *Earth Force:* is the magnitude of the gravitational interaction between the Earth and a given body. As a result, both forces act on both bodies (Earth-body) which in accordance with the third Law of Newton have [10,11]:
- Equal numerical value.
- The same direction and the same sense of the force.
- They act in different bodies.
- The same nature.

The expression of this force is:

$$F = G\frac{M.m}{R^2}, \tag{1}$$

and for the areas close to the planet:

$$G\frac{M}{R^2} = g, \tag{2}$$

F=mg is the force with which the Earth acts on the body. The corresponding reaction having the same value acts on the planet and taking into account the difference that exists between the mass of the Earth and the mass of the common bodies, for example, an apple, it is easy to calculate that in one second the latter moves along 5m whereas the Earth moves covering a distance of $2\text{x}10^{-25}$ m.

Weight force [5]*:* is the magnitude of the elastic interaction between a body which, due to the gravitational action, exerts pressure on a support or pulls a string, a spring, etc. As a result, the body and the support are acted upon by both forces which comply with the four characteristics of the 3rd Law previously described [1].

Thus, the figures represent the forces caused by the gravitational and elastic interactions.

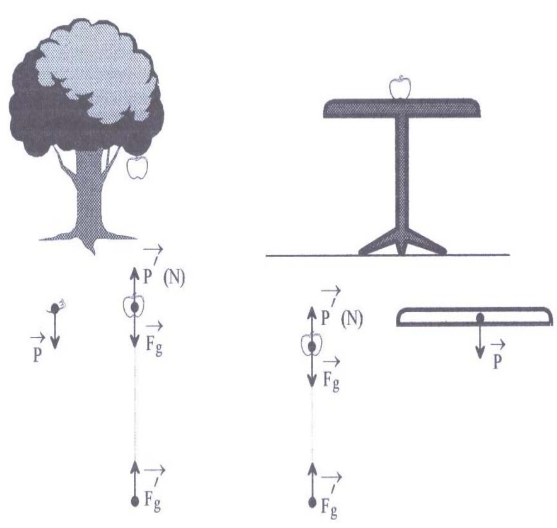

FIGURE 1. The forces caused by the gravitational and elastic interactions.

In any of the two cases the apple is in perfect balance because the external forces on the same are in compensation (2nd Law):

$$\vec{F}_g + \vec{P}'(\vec{N}) = 0. \tag{3}$$

Let us observe that the weight acts on the branch and on the table with pressure (elastic force).

Let us see a simple but clear experiment to clarify these ideas [2] .

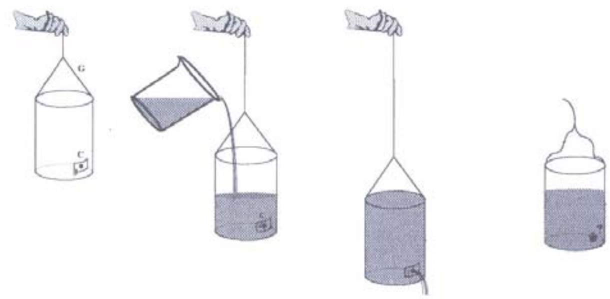

FIGURE 2. Can of soft drink or beer.

The Figures represents a can of soft drink or beer. A hole has been made (J) near the bottom of the can and this is covered with adhesive tape (C). The top part of the can is totally opened and is tied with an elastic band (G).

If the can is slowly filled with liquid, we can observe how the elastic band becomes more and more deformed. When the can is full, the adhesive tape is removed and the students are asked: Why is there a jet?

The answers we may get are:
- Due to the force of gravity.
- Due to the atmospheric pressure.
- Due to the weight of the water.
- And a smarter one would say: because it has a hole.

The answers should be written on the board together with the definitions of the forces.

Then the can is filled and is dropped. It is surprising to note the absence of the jet during the free fall. At this point we ask the question: Why is there no jet? And the answers written on the board are reviewed.

The elastic band should be of a bright colour. The experiment is repeated several times and the students´ attention is called in reference to what happens to the elastic band before and during the fall.

We come to the conclusion that on the whole and by definition, water is always attracted by the Earth and the atmosphere is always present. Thus, what disappears is the weight of the body.

When the elastic band is tied to the can, the water being naturally attracted by the Earth presses its weight directly upon the container and the elastic band is deformed because the can interferes with the fall onto the Earth. There is pressure in all parts of the container except for the part where the hole is located, which is now devoid of the adhesive tape and that is why the jet is produced. Once the elastic band is released, the water-can system falls under its exclusive interaction with the Earth. The elastic interaction, the weight, disappears.

The jet disappears because the whole system falls freely without any deformation. There is no weight: there is weightlessness [9]. There is no absence of gravity. At all events, there is only gravity.

Actions are repeated after this and the can is thrown towards the same direction and towards the same sense of the force of the jet that is downwards. Before this is carried out, a question is asked: what will happen to the jet? We may get answers like ‘The jet will be reduced’. It is evident that the result will be the same as in the previous case. The definitions, concepts and reasoning used in the previous case are repeated until the conclusion is reached.

The experiment must be repeated, but now the can is thrown towards the direction opposite to that of the jet, that is, upwards. In an attempt to mislead the students we can mention what happens when a road tanker having a hole in its roof and full of water, brakes or accelerates abruptly.

We will still get wrong answers such as: the jet will be increased. Going back to the reasoning applied to the explanation of the free fall, the following points are emphasized:

-Only the Earth and water-can system interact, (Gravitation),

-The elastic interaction disappears (Weightlessness),

-Only the Earth force causes the acceleration of gravity (vertical) and obviously not the speed.

We can imagine that we have already clarified the difference between Earth force and weight but we still have a trump card. Now the can is thrown upwards with great strength, in fact with all our strength. (Probably some of the students will move away so as not to be wet). What will happen to the jet?

As expected, the jet disappears for the same reasons exposed before.

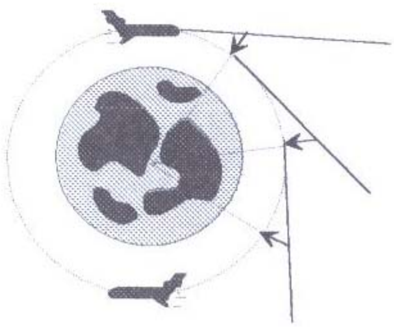

FIGURE 3. The spaceships that circumnavigate the Earth.

What happens in the spaceships that circumnavigate the Earth is essentially the same. The only difference is that the spacemen play the role of the water in the experiment and the objects in the spaceship play the part of the can.

Only the spaceship and what is contained in the same interact with the Earth. As a result, gravitational forces are produced and these are practically of the same value as those acting at the takeoff. (The distances are 6000 and 6300 km respectively).

The spaceship constantly falls toward our planet (otherwise it would go in a straight line through space), with a slightly lower acceleration than that expected it would have on the earth surface.

In other words, it is in a state of weightlessness and not in a state of absence of gravity, as is usually said.

As is usual with any other liquid, water takes a spherical form. Raindrops would be perfect spheres if they fell on empty space. Thus, during the moment of weightlessness, liquids have their own form: spherical.

Another situation which is worth mentioning is what happens in a lift that can move along a tunnel as far as is necessary [3]. Let us situate a lady inside our ideal lift and a man on Earth, with the possibility of communicating through telephones and television sets.

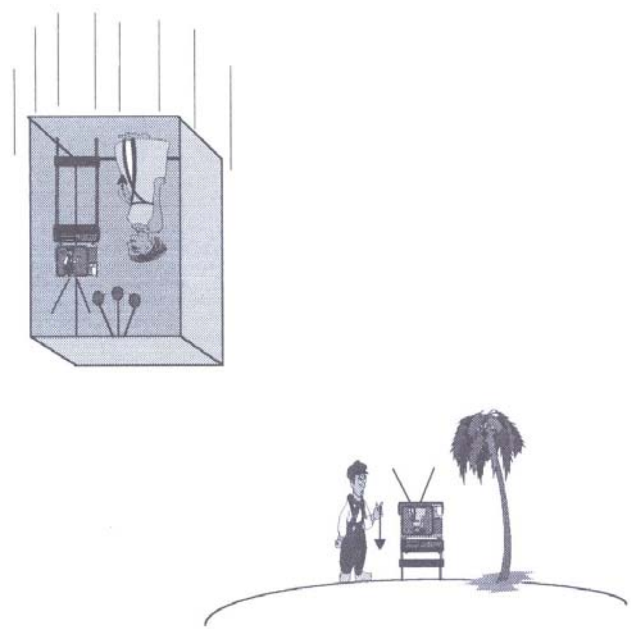

FIGURE 4. A lady inside our ideal lift and a man on Earth.

It is known that the weight of the lady can be determined by $P = m(g \pm a)$. The weight is increased if the lift is sent upwards (overweight) and the weight decreases if the movement is downwards (regardless the direction of the movement). If the cable that holds the lift is broken, the weight is equivalent to zero (there is no weight) and it is in the state of weightlessness. It does not matter whether the lift is going up or going down or is not in movement at the moment the cable breaks.

Let us now imagine that the lift is put into motion by an emergency engine which gives it an acceleration of 2*g* towards the same direction and the same way as *g*. What happens to the lady?

After a few seconds the students start discussing as to who is upside down. At a certain moment, the lady calculates the value of *g* by means of the classical experiment of the pendulum and obtains 9,8m/s^2. Where is the Earth? asks the young man. Well, where will it be? Under, answers the lady. You're crazy …

This experiment is simple and the results are clear and do not give way to doubts. In the same way, it refers to conceptually very strict ideas and deals in depth with the concepts of force, acceleration and the three Laws of Newton in relation to mechanical movement.

Albert Einstein, according to his biographers and to his own confessions, constantly used to put his intellect under two situations:

- He imagined himself inside a tube of light.
- He imagined himself inside a lift.

From his first mental adventure we can imagine his conclusions in relation to the Special Theory of Relativity. From the second one we see the General Theory of Relativity, in which he defends the Principle of Equivalence between the field of force and an accelerated system.

III. RESULTS

About all this we have find results very satisfactory in all students; better class work and home work, the class participation oral and written is richest in quantity and quality. We have proposed this method of study to several teachers and all of them agreed that they have achieved a better motivation in them to realize experiments simples but of a great value educational.

Front the point of view of the Physic, for all the students this method is logical and coherent. It is so simple as to allow the systematic application of one of the physical law that we considerer essential: the third law of Newton. Never the less, the most favorable results have been our method logical point of view. This didactic work to let know the students what is coming and what his reactions, to provoke the alternatives actions and ideas or pre-conceptions, all this and the patient in the process and to keep in the process of work, has created a interesting pedagogic system.

IV. CONCLUSIONS

This methodology applied to the “Weightlessness vs. Absence of Gravity” has been used in different groups of students and it has helped in obtaining very good results not only in the understanding of the topic but also in the acquisition of knowledge. It has also been presented to different groups of teachers of Physics in different countries and they have considered the possibility of using the same method in their teaching of Physics.

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