Is the ISS under ZERO gravity?

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In countless programs and interviews conducted by the media, whether oral, written or televised, some physicists, some physics professors and other less enlightened people insist on stating that the ISS is in zero gravity. And, more seriously, based on the fact that gravity is zero (according to them) 400 km above the Earth's surface (at the height of the ISS), they categorically state that the ISS maintains its orbit around the Earth only because of suffering repeated free falls.

Let's look at these claims from a more scientific perspective. Any physics textbook teaches that bodies on the Earth's surface are under the action of gravity. Rounding down, we can say that Earth's gravitational acceleration is $g = 9.80\ m/s^2$. Furthermore, this gravity generates a gravitational attraction between bodies. This causes bodies at rest to remain in contact with or close to the Earth's surface.

Now, let's do a brain exercise: suppose that, by snapping our fingers, we can zero the acceleration of gravity and eliminate the atmosphere.

What happens to bodies that are close to the Earth's surface?

Well, if we don't have an atmosphere and gravity, there's nothing to stop bodies that are stationary and not anchored to the Earth's surface from flying through space with small perturbations, such as small earthquakes.

Suppose a satellite orbits the Earth due to gravity and this generates an attractive force towards the center of the planet. At a certain point, gravity ceases to exist. Therefore, nothing prevents your route from being radically altered. As? Well, we know that the satellites in their orbits have fairly constant speeds (in magnitude), but their orientation changes all the time because it's always tangent to their orbit. This is true if gravity exists. As we assume there is not, there is no reason for the satellite to maintain its orbit. In fact, it will go exactly in the direction of your speed. As mentioned earlier, the direction of velocity is tangent to the orbit and its direction follows the sense of rotation of its angular velocity. So, obviously, the satellite will follow this trajectory, going to infinity.

If the acceleration due to gravity is zero, this is exactly what would happen on the International Space Station. It cannot stay in Earth's orbit, and is destined to go to infinity.

The funniest thing about this whole deception is that it took over all the media. Every time they report about space, everyone silently accepts this blasphemy. Perhaps readers still have doubts about these claims. Let's do a more rigorous analysis using resources from physics textbooks. Let's take Halliday's book [1] as a basis.

Mathematical Facts

It is important to note that in this analysis, we have ignored some details that lead to an error of less than 2%. First, let's prove mathematically that the gravitational acceleration of the ISS orbiting the Earth is not zero. To demonstrate this, using Halliday's book [1], we can write the equations that describe gravity as shown in the book, in Equation 13-9 (page 32), reproduced below.

$$F = G \, \frac{M_T \, . \, m}{r^2} \tag{1.1}$$

And according to Newton's second law, the magnitudes of F and g are related by equations 13-10 in the book (page 32) as follows:

$$F = m \;\, g \tag{1.2}$$

Substituting equation (1.2) into (1.1) and canceling the mass m, we get an equation that allows us to calculate the acceleration due to gravity at a point above the Earth's surface. When we refer to the International Space Station, we call g_I the acceleration due to gravity where it is located.

$$g_I = G\ \frac{M_T}{r^2} \tag{1.3}$$

We must remember that the distance in the denominator of equation (1.3) represents the sum of the Earth's radius and the height of the object above the Earth's surface.

The values of the variables involved in equation (1.3) are [1]:

- $M_T = 5,98\,.\,10^{24}\ kg$
- $G = 6,67\,.\,10^{-11}\ \frac{N\,m^2}{kg^2}$
- $R_T = 6,37\,.\,10^{6}\ meters$
- $h = 4,0\,.\,10^{5}\ meters$

Let's calculate the value of g_I in the ISS orbit.

$$g_I = \frac{G\ M_T}{(R_T + h)^2} = \frac{6,67\,.\,10^{-11}\,.\,5,98\,.\,10^{24}}{6,37\,.\,10^{6} + 4\,.\,10^{5}}$$

Carrying out the calculation, we find:

$$g_I = 8,7\ m/s^2$$

As we have already stated, there is a lot of gravitational acceleration in the orbit of the ISS. That is, about 12% less than on the Earth's surface. So the claim that we have zero gravity where the ISS orbits planet Earth is pure blasphemy.

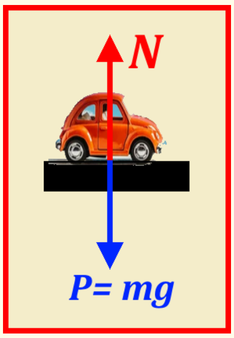

Figura 1

But, after all, in the orbit of the ISS there is an absence of what magnitude?

Well, what doesn't exist in the orbit of the ISS is a quantity called WEIGHT. First we must define the quantity weight. Using Figure 1 as a reference, we can identify the following variables: Force-Weight (P) and Normal (N). In the figure we see a car being supported by a fixed platform.

In this case, we have two forces acting on the car. One called Force-weight, which is the force of attraction provided by the acceleration of gravity, and another, called Normal force, which is the reaction that the platform exerts on the car. This is due to Newton's third law:

"A body at rest or in uniform rectilinear motion (MRU) the action and reaction have the same magnitude and direction, but opposite sense."

This is exactly what we see in Figure 1. And the definition of Weight is directly linked to the existence of the Normal force. Without Normal, there is no Weight. The force-weight continues to exist, provided by the acceleration of gravity. This is the case of a body in free fall, where we have the force-weight acting on the body, pulling the body towards the center of the planet. However, there is no Normal force, as the body is not supported. Therefore, the weight of a body in free fall is NULL. This Einstein had already completed at the beginning of the 20th century.

But how to coherently describe the orbit of the International Space Station and why do astronauts float in it?

First, let's explicitly state that there is gravity in the orbit of the International Space Station. Second, there is an approximately constant velocity that is tangential to the orbit. However, its direction varies from moment to moment. When the astronaut floats, there is no support, so his weight is zero. What if it was in contact with the spaceship? It's the same thing, because as the spaceship has no support, its weight is also zero. But, it was said that, in this case, the Force-weight continues to exist. Why doesn't the spaceship fall towards the planet? Simple. Don't forget that we have a velocity tangent to the orbit, with a very large value (as we will calculate later) and that tries to throw the spaceship-astronaut set towards infinity at all times. But, exactly, the Force Weight does not allow that to happen, keeping spacecraft and astronaut in orbit around the planet. So, whatever position the astronaut is in, he will float. And that challenges the claim that the ISS is always in free fall. And to this force-weight, Physics gives a special name, calling it Centripetal

Force. Centripetal force is described through equation (1.5).

$$F_C = m\,\frac{v^2}{r} \tag{1.5}$$

Therefore, since the forces must be equal, we can write:

$$m\,g_I = m\,\frac{(v_I)^2}{r} \qquad \longrightarrow \qquad v_I = \sqrt{g_I\,r} \tag{1.6}$$

Remember that $g_I = 8,7\ m/s^2$ **e** $r = R_T + h = 6,77\,.\,10^6\ metros$**, we get:**

$$v_I = \sqrt{8,7\ .\ 6,77\,.\,10^6} = 7.675\ m/s$$

This speed can be converted to km/h **by simply multiplying the above value by the correction factor equal to** 3.6**. Applying it, we get:**

$$v_I = 27.628\ km/h$$

It is important for the reader to note how fast the ISS orbits the planet Earth, taking an average of 90 **minutes to go around the planet completely.**

Therefore, the fallacy of the statement that the ISS orbits the planet Earth in the absence of gravity must have become very clear to the reader.

And of course, one might ask: but if there is no weight in the orbit of the ISS, how are we going to measure the body mass of astronauts? Well, in Physics there is the well-known Harmonic Oscillator that allows calculating the mass of astronauts in a very ingenious way. But, that is a subject for another topic.

So, the next time someone makes the argument that the ISS orbits planet Earth in the absence of gravity, the reader has both a scientific and mathematical basis for disputing this fallacy.

Reference

[1] - HALIDAY RESNICK - Fundamentos de Física - Vol. 2 - 8ª edição - Ed. LTC - 2009.