The Equivalence Principle

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In formulating his General Theory of Relativity, Einstein described its fundamental postulate, the principle of equivalence, using as an example a physicist closed in a box (size not relevant). He insisted that a physicist inside could not tell the difference between gravity and acceleration. This writer analyzes this prediction and the equivalence principle by reviewing Einstein's original thought experiment.

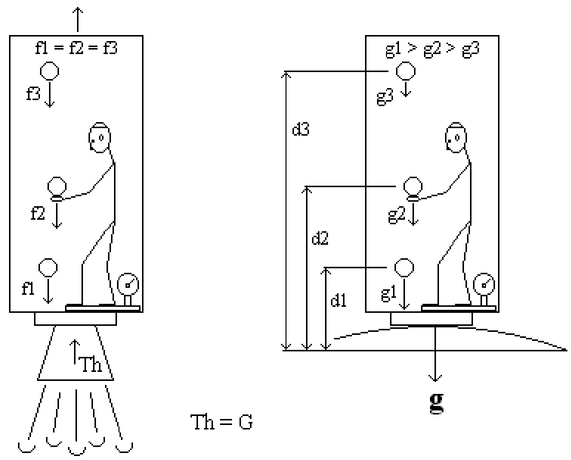

Fig. 1. Equivalence example 1: rocket vs. gravitational field.

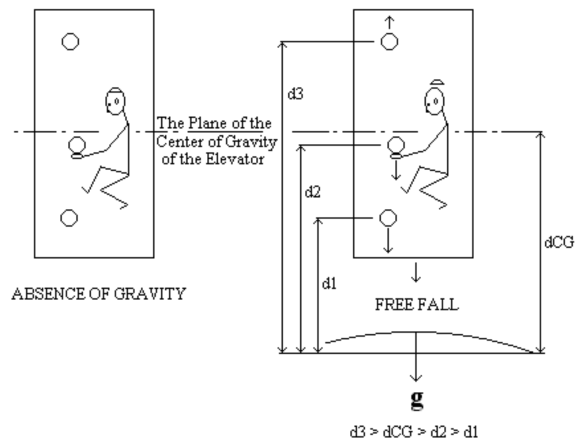

Fig. 2. Equivalence example 2: absence of gravitational field vs. free fall.

Fig. 1 shows two boxes having identical interiors with the "physicist" standing on scales, dropping an apple toward the floor. The exteriors differ, one showing the box standing on the ground (Earth's surface), the other having ignited rocket engines installed under the floor and surrounded by free space.

Textbooks claim that "it is not possible, by doing experiments within the box, for the physicist to tell which box he is in." [1]

We argue that gravity actually changes with distance d_2, and that gravity is less near the ceiling than the floor. We also argue that the gravity is recognizable, since we don't have an elevator height limit. It can be, let's say 10 or 15 meters high. As mentioned above, the size of the box is irrelevant, because the function d_2 is valid also on a microscopic scale.

The physicist in the box resting on the Earth's surface would be able to indicate and calculate the difference between the gravity value near the ceiling and near the floor. The body g_1 at the distance d_1 from the gravity source is larger than g_2 at the distance d_2, which is larger than g_3 at the distance d_3.

In the box propelled by the rocket engines, all objects in all positions will have the same acceleration relative to the box due to the force applied (only) on the box.

Now, Fig. 2 also depicts identical interiors, and shows the physicist weightless in the elevator, drifting in space in one picture and falling toward the earth in the other. Textbooks claim: "it is not possible, by doing experiments within the cab, for the physicist to tell which box he is in".

In the box drifting in space, objects inside keep their relative positions, being influenced only by mutual gravity of the mass of the box and other objects in proximity.

However, in the case of free fall, all objects are subjected to gravity, also with respect to the distance. Therefore object(s) situated above the elevator's weight-point plane (which determines the box gravitational acceleration), will move (accelerate) toward the ceiling.

One can notice the scientist's yarmulke flies off his bald head, because it is situated above the elevator's center of gravity.

Objects placed below the elevator's center of gravity plane will tend to move (accelerate) toward the floor, reacting to the distance factor d_2. Thus, a high school educated observer would be well aware of presence of the gravity.

It is a fashion to argue that the difference is so small anyway, that it can't be detected. To invalidate this argument, we just need to mention that at the bottom of the third next page of the same textbook is a sample problem involving the gravitational force between two dancers at the 10 meters distance. (!?!)

Conclusions drawn from the analysis generally hit hard (quite arrogantly) with Einstein's opinion on which he based General Relativity. He wrote:

> "The general theory of relativity owes its origin to the attempt to explain a fact known since Galileo's and Newton's time, but hitherto eluding all theoretical explanation: the inertia and the weight of the body, in themselves two entirely distinct things are measured by one and the same constant, the mass. From this correspondence follows that it is impossible to discover by experiment whether a given system of coordinates is accelerated, or whether its motion is straight and uniform and the observed effects are due to a gravitational field (this is the equivalence principle of the general theory of relativity)." [2]

Today we certainly have the methods and instrumentation that Einstein didn't have at his disposal in 1915, with which we can indicate and identify the gravity vs. inertia. Therefore we cannot escape from the inevitable. Let's continue with Einstein:

> "The chief attraction of the theory lies in its logical completeness. If a single one of the conclusions drawn from it proves wrong, it must be given up." [2]

Thus, when Relativity Theory, both Special and General have to be discarded, it is only fair that this would be done on Einstein's terms, unless resisted by one versed on (Einstein's) Relativity Theory better than Einstein.

Is an Orbiting Satellite in Free Fall?

Can we recognize the difference inside a spacecraft? A widespread opinion is that an orbiting satellite behaves as if in free fall. This opinion is also based on the relativistic equivalence principle disputed above. Let's look again on the Fig.2 – free fall.

$$d_3 > d_{CG} > d_2 > d_1$$

This means that the body above the plane of the spacecraft center of gravity (CG) moves toward the ceiling, being more distant from the gravity source (planet), and bodies below the center of gravity move towards the floor. This demonstrates free fall toward the planet.

On the other hand, in the spacecraft on the orbit around the planet, free bodies above and below the spacecraft center of gravity (Fig. 3), having the same horizontal velocity v as the spacecraft, will act differently.

The velocity of the spacecraft determines the orbit level, leading through the center of gravity of the spacecraft. Therefore, the body above the center of gravity tends to move toward the "ceiling", but it also retracts relative to the spacecraft body velocity because its distance from the source of gravity $r_2 > r_{CG}$. Therefore, its orbit $2\pi r_2 > 2\pi r_{CG}$. This makes its upward movement angular toward the trailing wall of the spacecraft.

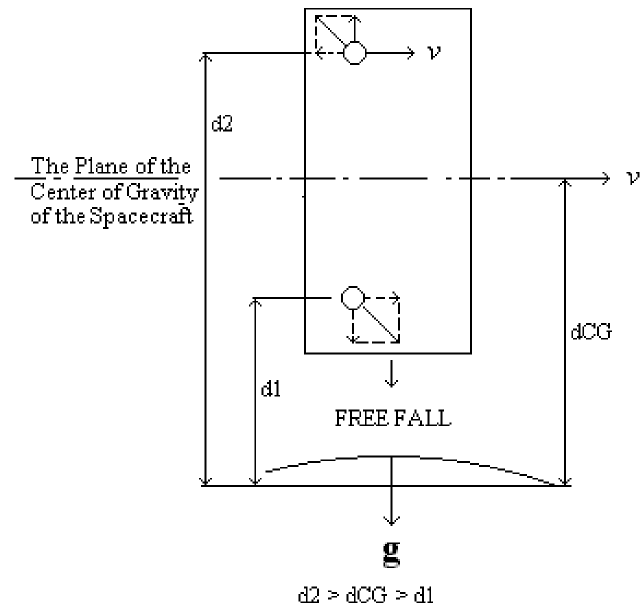

Fig. 3. Free bodies above and below the spacecraft center of gravity (CG)

The body below the center of gravity tends to move toward the "floor", but also advances relative to the spacecraft body velocity, because its distance from the source of gravity $r_1 < r_{CG}$. Its orbit is $2\pi r_1 < 2\pi r_{CG}$. This makes its downward movement angular toward the front wall of the spacecraft.

It is conclusive that a satellite in orbit is NOT (solely) in free fall, because of the horizontal velocity added, a centrifugal tendency equal to the centripetal force actually prevents it from the real free fall movement.

References

[1] David Halliday, Robert Resnick, **Fundamentals of Physics**, pp. 349, 352 (John Wiley & Sons, 1988).

[2] Albert Einstein, **Ideas and Opinions**, pp. 227, 321, 340 (Dell – Laurel, 1981).