Gravity and Freefall

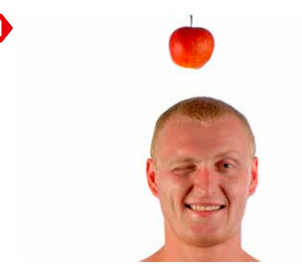
The term Freefall immediately calls to mind the image of the Austrian adventurer Felix Baumgartner who, on October 14, 2012, became the first person to jump out of a helium balloon from a height of 38,969.4 meters, plummeting toward Earth for around 36.5 km without the aid of any aircraft. The maximum velocity reached by the forty-three-year-old extreme sportsman was 1,357,6 km/h. One of his goals was to break the sound barrier at Mach 1.25 (the speed of sound is approximately 1,235 km/h), which he clearly succeeded in doing. Around 2,500 meters above the ground, he pulled the ripcord of his parachute to slow down, and eventually made a safe landing.

It is hardly necessary to take the risks that Baumgartner took in order to experimentally investigate and understand the principle of freefall and the associated parameters, laws, and calculations. A simple construction will suffice.

History

As early as 55 BC, the Roman poet and philosopher Lucretius explained that falling objects are only slowed by hydrodynamic or aerodynamic resistance, and that lightweight bodies fall slower for this reason, but that all bodies must fall at the same rate in a vacuum.

In the opinion of the Greek philosopher Aristotle (384–322 BC), heavy bodies must fall to earth faster than lighter ones, since they sink in water, whereas lighter bodies rise. Not until 1554 did Giovanni Battista Benedetti (1530-1590) disprove Aristotle's assumption. He showed that two identical spheres firmly connected to one another by a (massless) rod will fall at the same velocity.



The opinion that a body moves at a constant speed while falling also comes from Aristotle. Not until 1590 did Galileo Galilei (1564–1642) posit the laws of freefall: In a vacuum, all bodies fall at the same rate, irrespective of their shape, composition, or mass. Their fall speed is proportional to the fall time, whereas the falling distance is proportional to the square of the fall time. This means that acceleration is equal for all bodies at the same point. In 1659, Robert Boyle confirmed through experimentation that bodies with differing masses fall at the same rate in a vacuum.

Definitions

"Freefall" describes the acceleration of an object exclusively due to gravity. People who jump out of an airplane are slowed by aerodynamic resistance as they fall. A true "freefall" would only be possible in a vacuum in which no forces other than gravity are able to act. A test environment for experiments of this kind can be found at NASA's Glenn Research Center in Cleveland, Ohio.

Equations

Freefall (without friction): The force acting on a falling body is denoted as F and is measured in newtons. A newton is composed of the mass of the body (in kg) and the acceleration (in m/sec^2), where the acceleration is equal to the earth's gravitational factor.

$$\text{Newton} = \text{kg} * \text{m/sec}^2$$

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Bodies with different masses fall at the same rate in a vacuum. For this reason, the general equation of freefall is as follows:

$$h = h_0 - 1/2\ gt^2$$

In other words, the calculation is independent of the weight of the body. Hard to believe, but in a vacuum a hippopotamus will fall at the same rate as an earthworm.

h = height of the body at time t, h_0 = initial height without initial velocity, g = freefall acceleration, t = fall time in seconds.

$$s = h - h_0 = 1/2\ gt^2$$

defines the distance covered by a body in freefall in time t when it is dropped from rest.

The acceleration of gravity is 9.81 m/sec^2.

$V = gt$ is the equation used to calculate velocity during freefall. In this equation, V is the fall velocity in meters per second, g is gravitational acceleration in meters per second squared, and t is the fall time in seconds.

We do not have a vacuum in which to conduct our experiments, however, we need to take atmospheric friction into account. This means that our experiments will not provide the correct acceleration for freefall.

Drops with Aerodynemic Resistance

Two opposed forces act on a falling object: weight force and drag force (in a vacuum, drag force = 0).

We can derive the maximum velocity of an object from these variables. As a matter of fact, the maximum velocity is reached precisely at the moment when both opposed forces are equally strong, leading to the object no longer being accelerated in its fall. A greater maximum velocity can be achieved during a fall with aerodynamic resistance either by reducing the aerodynamic resistance or by increasing the mass of the body. The following applies to falls with aerodynamic resistance: The heavier the object, the greater its maximum fall velocity (assuming the same shape and surface characteristics).

Felix Baumgartner tried to reduce the aerodynamic resistance of his protective suit in order to reach supersonic speeds as quickly as possible. After that, he increased the resistance by opening the parachute in order to slow down before reaching the ground.

People Associated with This Topic

- Galileo Galilei
- Isaac Newton
- Robert Boyle
- Giovanni Battista Benedetti

You Can Find Informative Websites Using the Following Keywords

- Freefall
- Glenn Research Center
- Parabolic flight
- Aerodynamic resistance

Internet

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