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Question 17: When two objects with different weights are dropped, why does the heavy one accelerate at the same rate toward the Earth as the lighter one?

Mr. Skyler:
I recently found a You Tube video titled "Misconceptions About Falling Objects" produced by Veritasium in which the interviewer was asking students to consider a test where two balls of different weights were dropped at the same time from the same height. Most students interviewed thought that both balls would reach the ground at the same time which I think is correct. But he went on to question why this was so considering that the heavier medicine ball had the greater gravitational force. The interviewer then gave his opinion that the heavier ball had a lot more mass which meant that it had a lot more inertia which he said was a "resistance to acceleration". I think he is telling us that due to the resistance force of inertia the greater force of the medicine ball's gravity is unable to cause anything more than the normal rate of acceleration of the lighter basket ball. Is his inertia explanation correct?

G.D., Cedar Falls, IA, USA

Hello G.D.:

What a charming and spirited interview. I have already addressed this issue in Question 11 but feel that it is important to consider such tests from every perspective possible. Physicists have attempted to answer this drop-test question for a long, long time. Galileo's experiments in the 1630s generally proved that falling objects accelerate at the same rate regardless of differences in mass ratings. He pointed out that Aristotle's teachings of nearly 2000 years earlier, where heavier objects were thought to accelerate faster, made no sense. Galileo imagined that if two light objects were bound together using a cord so as to form a single object that was slightly more than twice as heavy, he figured that when dropped, there could exist no logical reason why this double object should now accelerate at a much faster rate than the rate of one of the light objects falling alone. Galileo is famous for this piece of logic along with his many experiments testing the acceleration rates of dissimilar falling objects.

Unfortunately the presence of air has an effect on any such test result. When dropped in air, a heavier object, given the same size, shape, and surface type as the lighter one, will always accelerate faster and reach the ground first. The heavier object possess a greater Earth gravitation force which, upon the object's release, will cause a higher terminal velocity against the increasing support force of air friction. Thus the heavier object keeps on accelerating while the lighter object's acceleration is being brought to an early end. If these objects are dropped in a vacuum, the pure truth will be revealed. Regardless of any difference in shape, size or surface type, both objects will reach Earth's surface at the same time, even if one is a hammer and the other is a feather. This "air friction effect" has surely caused a lot of debate, especially in the neighborhood of the leaning tower of Pisa, which is suggested to be one of Galileo's drop test sites. Clearly the vacuum test results are used as the basis for today's generalized conclusion that all dropped objects accelerate toward Earth's surface at the same rate. When performing drop tests in air, it would be more accurate to say that all dropped objects "initially" accelerate toward Earth's surface at the same rate.

Clearly there is more to this story concerning exactly why the heavier object, with its greater forces of gravity, when dropped within a vacuum chamber, can manage an acceleration rate that is no greater than the rate of a lighter object. While developing the answer there is no need to turn to the empty concept of "inertia" for support by making reference to an imaginary "resistance to acceleration" or "inertia force" to explain the result. Instead all that is needed is an understanding of the internal forces present within matter and the roles they play during a weighing event which instantly turns into an accelerating event once the object's support is lost.

Acceleration is the change in an object's velocity which includes an object speeding up along its straight-line path, slowing down along its straight-line path and/or turning to one side from its former straight-line path. Acceleration of any object always requires the presence of an acceleration/Action force with its vector pointed in the direction of the acceleration. Also no acceleration of an object can possibly occur while an acceleration/Action force is absent. Thus an object observed at rest has no other choice but to remain at rest until such time as an acceleration/Action force that is capable of causing acceleration for the object becomes present. This resting object does not just "tend" to remain at rest like it has some option other than remaining at rest. No, remaining at rest is the object's only option. As long as acceleration/Action forces remain absent, rest is the object's only choice. In fact, rest is the object's default state that automatically occurs to the object the moment the acceleration/Action force ends.

What about motion? Where does motion fit in? If acceleration is caused only by force and rest has no direct cause, only that acceleration forces be absent, then what causes motion and how does motion relate to rest? It helps to recognize that rest and motion are two different names for the same state for an object. Newton wrote of their connection as he viewed rest and uniform motion as being the same equally inactive state for an object. But unlike with Newton, we see no agent is required to actively maintain the non-accelerative state known as rest or uniform motion for the object. Let this inactive state where the action of acceleration is absent be known from here forward as rest-motion.

Returning to the drop test, to properly explain this event, it is crucial to understand that an internal force, such as Earth gravitation, is being generated separately within each component of an object's matter. Prior to dropping the two balls, these internal gravity forces stack up or accumulate in the downward direction to produce the external (contact) force of each ball's weight against the interviewer's hand. Once the balls lose the support forces from his hands and Earth below, they instantly begin their accelerated motion toward the ground. The acceleration/Action force is the same individual Earth gravity forces being generated within the interior of each ball's myriad of components of matter. These internal forces present within the accelerating components no longer stack up in the downward direction. Instead the gravity force within each component is fully spent accelerating that component, initially at the rate known as small "g". No force is left over to act as the cause of any external event such as weight. Thus the components of each ball are initially weightless when dropped as if the components of matter of the object being dropped are as disconnected from each other as as those within a hand-full of dry sand.

Weight is the external force one object freely bears against a second object. Suppose we measure the weight difference between the two balls, form a blob of sticky clay whose weight is equal to this weight difference, divide this blob into 4 equal parts and then drop the first clay part alongside the light basket ball. Following this short drop, both objects will reach the ground at approximately the same time which is no surprise. Both the light ball and the 1st clay part, due to the quantity of their matter and the equal treatment of gravitation, automatically generate just the right amount of Earth gravitational force to cause the same normal rate of acceleration for that quantity of matter in Earth's direction. Now we paste the 1st clay part to the basket ball and pick up and drop the now heavier ball alongside the 2nd clay part. Again both objects hit the ground at about the same time. We can keep pasting the remaining clay part only to find that each time the heavier and heavier basket ball is dropped, its accelerated fall continues to be at the normal rate of g. When all 4 clay parts are pasted to the basket ball it will now weigh the same as the medicine ball but will once more accelerate toward Earth at the normal rate.

What can be learned from this event? Gravitational acceleration of any object is powered by internal gravitational forces being generated separately within each of the object's myriad of components of matter. These internal forces stack up to form the external (contact) force of weight when the object is supported. But when dropped, these same internal forces, which are always proportional to the object's mass rating, are fully spent causing normal acceleration for the object or portions thereof which on Earth is at the rate of g, which is 32.17 ft/sec/sec or 9.8 m/sec/sec. Once you understand these terms and actions, the answer to this age-old question is within reach. Each clay part added will increase the basketball's external force of weight, but when dropped, the added clay part only brings with it enough gravity force to cause its own acceleration at the normal rate at your location on Earth. Since each clay part's internal gravity force is terminated in causing this accelerational action, no gravity force from that part is left over to increase the acceleration rate of the rest of the weightless basket ball. For this reason, adding matter to the object will not bring about much change to its rate of acceleration when dropped from a low height.

An object in rest-motion is not in a state caused and maintained by the presence of Newton's imaginary "inertia force". Instead the rest-motion state of an object only requires that an acceleration/Action force be absent. Thus the state of rest-motion is a causeless event, one that automatically occurs when all a/A forces are absent. When an a/A force does show up, the object immediately abandons its rest-motion state for one where force is causing acceleration according to the dictates of the Newton-based formula, $a = F / m$. Finally, Newton granted his imaginary "inertia force" the impossible characteristic of maintaining an object's inactive state of rest-motion by itself which curiously is in violation of his own perfectly correct third law. No force can exist alone. Our a/A force has no such problem since it generates its own mutual acceleration/Reaction force reflected back from deep within the components of matter of the accelerating object, exactly as required by Newton's LAW III.

Thanks for presenting the opportunity to sort through some physics concepts alongside the old timers.

Ethan Skyler
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