Galileo's Mistakes

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Abstract: The inspiration for this paper arose at my chalet here, high in the French Alps, ten years ago when proximity to nature encouraged my continued reflection on the physics taught when I attended the College of Technology, Belfast, Ireland, aged 14 in 1947. [The Journal of American Science. 2007;3(3):85-88]. (ISSN: 1545-1003).

Galileo reputedly proposed that different bodies fall with the same acceleration, and that their distance traveled is the square of the time taken.

One of the portrayals of the seeming similarity, was with a lightweight ball of paper and a heavy inkwell, which both reached the ground apparently simultaneously after being released from outstretched hands. That phenomenon had always puzzled observers, because they expected heavy bodies to fall more quickly than light ones. Nobody explained why. In order to confirm the apparent similarity, Galileo tried controlled experiments with measurements. They persuasively evoked that proposal, and revealed that falling bodies accelerate (that's movement increasing its distances in similar times). Extraneous effects are discounted.

HOWEVER, it seems that Galileo still did not explain how similar acceleration could happen.

MOREOVER, his measurements – of distances (evidently increasing), and of related quantities (apparently equal) which he linked to time – were unavoidably approximate.

Therefore this paper tries to elicit what the missing explanations might be ; in order to judge whether his similarity and squaring accord with reason.

(A) Similar Rates of Fall?

(i) Perception

It can be observed that the cause of such falling is Earth's gravity, which may be taken to be an influence by matter causing a mutual tendency to move. Galileo may not have fully appreciated, that terrestrial gravity is millions upon millions of times bigger than the ball and the well. That's an immense centripetal (towards center) influence acting on those of minuscule objects. Thus their respective reactions would probably be in the ratio of their sizes to that colossal attraction - each a minuscule fraction. Size could be measured by the force of weight, which may be taken to be the tendency of any entity of matter to move in the same direction as a greater influence.

All Galileo's experiments had similar relative minuteness.

Since the difference between such tiny fractions would be imperceptible to ordinary observation, the lengths of time for the two descents would appear the same. For comparison, think of how any different sizes of two pinpricks could not easily be seen; or of how we don't feel the deducible movements of referential Earth.

(ii) Reaction Time

Such reaction to that great scale of gravity can only be compared with everyday examples of relatively small applications of force, whether acting to or from. Nevertheless, anyone can observe that reaction is always time-consuming and progressive. Innumerable examples include:

FIRST, those of PREPARATION:

(a) Drops develop *from time to time* at the bottom of a hanging wet cloth.

(b) If a marble is dropped on a hard horizontal surface, the little ball bounces. The rebound probably results because the hardness is caused by innumerable constituent parts holding firmly together by centripetal force. Thus the point of contact is likely to be influenced mutually by so many parts that their combined time to react can not accommodate straight away the marble's impetus. Therefore its own force is hardly influenced, so it remains motivated. Yet it cannot continue downwards, so that force can only cause it to retrace - a change of direction, not evidently of movement.

Then its own newly-upward-acting force *takes further time* to adjust to the continuing influence of Earth's gravitational force, until the total effects of each of the two forces are equal ; thus at virtually half the preceding descent, where the marble stops. Next having only that distance to fall, the marble adopts less impetus, and thus applies less of its force to a possible second rebound. Accordingly, a second stop is at about half the distance of the previous one, and this reducing series might continue likewise.

All the bouncing illustrates that gravity's effect is not instantaneous.

Rather it takes time to induce movement towards itself - as with the drops.

Incidentally, in mathematical theory, the continual halving of half would never come to zero. Yet mathematicians should not expect the marble never to stop bouncing : it would come to rest when its impetus has reduced to the extent that the mutual reaction during impact equals its weight (because in fact, the 'halves' are, again, imperceptibly different).

SECONDLY, those of progressive action and its relation to SIZE:

(c) The center of a grilling steak can still be rare when the outside is sealed; larger/smaller steaks cook respectively more slowly/more quickly with the same heat ; any change in heat causes related change for the time needed. Movement might take place as burning.

(d) In a chain gang, the leader could only make a break for freedom after the time necessary for each prisoner in sequence to react to the precedent. In the same way, their accelerations from walking to trotting to running would each require time to come into effect. Therefore a big gang would take more time than a small one to cover the same distance.

Similarly, it seems logical that gravity would influence the nearest part of a body before the motivation could pass to other parts in sequence ; so that they can come into movement or increase it, en bloc. That's like the drops too.

(e) Reaction time is also intrinsic to one definition of a newton, which is reputedly 'the force acting for a second on a free mass of 1 kilogram to induce a velocity of a meter per second'. Although that does not lend itself to practical illustration even with a dynamometer, logic suggests that a newton acting on a mass of 2kg would require more than the first second to induce the same velocity. Big is slow!

Mass might be taken as the scope of any entity's tendency to move. Yet it is not clear whether the 1kg mass is supposed actually to move, or not, during part or all of that first second.

Incidentally too, all force, probably pulsing multi-directionally, seems associated with movement, either visibly actual, or potential when at relative rest.

Movement may be taken to entail pulsation's acting more in one direction than in all others together.

(iii) Direction

Although such reaction-delay was not obvious with Galileo's minuscule objects, similar effect could be visualized with a large moon brought suddenly into range of Earth's gravity. It seems unlikely that the centripetal force of all that moon's constituent parts could change simultaneously and instantly to the direction of falling. Rather it is probable that they would take time for coordinate change, proportionate to corporate size, before moving and during descent. That again is like a chain gang, and like one kilogram or more influenced from rest by a newton.

Therefore: a large body would fall more slowly than a small one.

Moreover, the lesser the net gravity, the slower again is any movement (compare reducing a grill). Thus if a man could be on the Moon, his lunar descent after jumping up could be expected to be slower than terrestrial ; as sometimes depicted on television.

Altogether it seems that:

Galileo's “same acceleration” is invalid.

(B) Squaring of 'Time'?

Galileo is also reputed to have deduced from his measurements (of lengths, and of water collected during descents) that the distance traveled by any falling body is the square of the time taken.

Again, it seems he did not explain how that could come about.

To question this idea: time might be taken as 'intervals', called the first (1), the second (2), and the third (3), etc.; distances, possibly 'units', could then be ONE (1 x 1), FOUR (2 x 2), and NINE (3 x 3), etc.

It seems likely that equal units of distance would be induced by equal units of gravity ([1] etc), in any one case, as also elaborated in the following subsections.

(i) Why 'units'?

The proposal in subsection A(iii) above is that a body, before movement can take place, takes time to react to gravity (already effected before terrestrial experiment, but must be accounted for). The extent of that gravitational influence, being the sum of its activity during the time, may reasonably be called a unit of gravity: first because it is unmeasured in this hypothesis; secondly because extent differs with different bodies [as suggested by subsections A(ii),(c)(d)(e)]. There is a certain analogy with the theorem of Pythagoras exemplified by any triangle whose sides can be divided respectively into 3, 4, and 5 units of length all equal - these units are greater the larger the triangle; and thirdly because action is virtually continuous, whereas unity permits association of similar gravitational extents with unitary distances [compare the definition of a newton A(ii)(e)] - during all intervals related to them, in each case.

Thus during the first part of interval one, a unit of gravity in total acts *in* the stationary body preparing it for movement. During the second part a similar unit[1]* induces ONE unit of distance. In each subsequent interval, two units of gravity are again identified because such duo was required to induce the first result, and because dual° increments are essential to the squared series ; as below.

(ii) Continuing Effects

After affecting the directional force of a body, every movement-induction by gravity becomes impetus (also essential to the series, but Galileo seemingly did not explain that). It conduces repetition of corresponding distance [see a definition of inertia ; compare again the velocity of the kilogram (A)(ii)(e)] - conjointly with that induced by continuing gravity (compare a liquid's flowing into a receptacle).

Consequently in a second interval', one distance-unit results by ' impetus evolved from the first interval, and, again conjointly, two by gravity[2]* - these influence all the body's force whether potential* or active. Thus three equal influences induce three units of distance, which, added to the first, make FOUR, in consonance with the squaring theory (compare one° newton's continuing to act on a ° kilogram – the cumulative number of meters would *never* be the square of the corresponding number of seconds!).

A third interval also experiences impetus, now three units [1+2]** and thus of distance to be traveled, which, with the earlier four, total seven units of distance. The other two, to make NINE conforming to the arithmetic, result again by two new units of gravity concurrently.

This series continues likewise, for 16 (total to interval 4), 25 (total to interval 5), etc. units of distance. Galileo's squaring is still all right.

(iii) Convenient Statement?

Yet further Galilean comparison can be made with the triangle of Pythagoras [see B(i)] : those three numbers squared are 9, 16, 25 ; each of these figures representing a certain number of equal squares (eg 3, on a side), each formed on a unit, and added the same number of times(3) = 9 squares. Thus the theorem respects the principle that only similar things (equal in the aspect considered) can be added.

For convenience, addition can be stated as multiplication (eg 3 squares x 3 = 9 squares). Thus equal things can only be multiplied by a number [being 'times' (x)], not by other things. Consequently, Galileo's "squaring of time" might still be justified as a convenient statement, but only if appropriate units are equal in any one case, as he apparently implied (he presumed time proportionate to flows of water related to distances of fall - each measured by equal units, but with inevitably limited precision relative to terrestrial scale ; nevertheless, they were perhaps sufficiently precise for practical purposes, if not for theory applicable from infinitesimal to infinite).

Yet influence, such as gravity, increases on any approach to source (like bringing the steak closer to the grill; compare also opening a tap). Thus, for example, if interval two' was the same length as one, more than three units of influence and of distance would result. Therefore, to conform to the series by similar inductions, all intervals shorten progressively as gravity increases.

Note again, that mathematics are not valid in physics if the figures are divorced from facts: since intervals are unequal: Galileo's “Squaring of Time” is invalid.

(C) Falling Restated

In the light of this analysis, it may be concluded that:

Large bodies within range of gravity greater than their own, fall *more slowly* than small bodies in similar circumstances.

In each case, size determines the relevant equal units of gravity inducing proportionate distance-units of fall, during related *unequal* intervals of time.

In every case, the total number of distance-units fallen, coincidentally equals the square of the *number* of appropriate intervals.

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Received: 8/23/2007