Revista Română de Filosofie Analitică,
Romanian Journal of Analytic Philosophy
Vol. XV, Ianuarie-Iunie 2021, Nr. 1, p. 39-46
ISSN (ediția electronică): 1843-9969,
ISSN (ediția tipărită): 1844-2218
DOI: 10.62229/rrfaxv-1/2

# GALILEO'S LAW: ON SOME ARGUMENTS CONCERNING FALLING BODIES

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***Abstract:*** A law saying that heavier bodies fall faster than lighter ones has been held to be refutable independently of empirical experiments, with a priori "thought experiments". I argue that these thought experiments do not qualify as good arguments against the law.

***Keywords:*** heavier, lighter, faster, slower, *a priori*

1. Among various theses called "Aristotle's Law" there is the claim (Faster) that, allowing for air resistance, a heavier body falls faster than a lighter one. The generally accepted verdict is that (Faster) is false. Just as Aristotle's name is associated with asserting (Faster), Galileo is noted for having refuted it. Whether he deserves the main credit for that has been disputed. Galileo has been credited with producing both empirical and a priori arguments against (Faster). My topic is just some arguments which have been said to refute (Faster) a priori, that is, without appeal to empirical observations. It should be appropriate to consider these arguments a priori, that is, without bibliography or history. The arguments will be considered solely on their merits, independently of who, if anyone, is advancing them. It is an empirical question whether this is of interest to anyone. I hold that it should be to any who cite these arguments as successful a priori refutations of (Faster).

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It would of course be valuable to know about the connections between Aristotle, Galileo and the words of (Faster) ("Allowing for air resistance, a heavier body falls faster than a lighter one"). Information about those connections is not a priori and has no necessary connection to the arguments to be discussed here. Galileo is frequently credited with having refuted (Faster) by purely logical, or a priori, argument. Whether he did that is not a matter of a priori analysis. Some arguments have been cited as constituting such a priori refutations. Whether they were produced by Galileo is not an a priori question. Whether they are good arguments is.

The arguments appeal to imagining experiments, rather than actually conducting any, and are called "thought experiments". Both (Faster) and the a priori counterarguments concern falling bodies. Like many concepts in common use, falling can become quite complex from a scientific point of view. I am not expert on the physics of free fall, in which the only force influencing the falling body is gravity. The application of this concept to a body in orbit is beyond my powers. I will confine myself to simple cases of dropping objects of different weights from a high place on Earth, where there are vertical drops of over 4,000 feet. A priori arguments against (Faster) have to apply to such simple cases and if they are deficient for those cases, they are deficient simpliciter.

2. We know that a body moving faster on a path will overtake and pass one that is moving slower. Whether this was learned a priori is a harder question. It is plausible that it could be so learned. Zeno argued that such overtaking is impossible–the faster can never overtake the slower. That would be clearer as the claim that the later starter can never overtake the earlier as long as both move continuously. His arguments could be classed as a priori. Whether they can be refuted a priori will not be settled here. It is true by definition that a body x traverses a distance in less time than body y if and only if x is faster over that distance. The Zeno arguments are usually interpreted in terms of a different, dispositional, meaning for "faster" which is not relative to a specific distance (though defined in terms of distance).

In the absence of injury or other obstacles the hare's standard pace completes a given distance in less time than the standard pace of the tortoise. Unexcused failure to overtake the tortoise on a given course could lead to logical conflict with that general credit for being faster. If the fox is credited with a speed of 10mph and the tortoise 1mph and the tortoise is given a one minute head start, and the motions are continuous, the speed credits logically entail that the fox will reach the 100 yard mark before the tortoise, which in turn entails overtaking the tortoise. Perhaps the Zeno arguer would deny that such being faster is possible. That would relate to the topic of falling faster.

3. (Faster) is about falling bodies. It says that for every x and y, if both x and y are falling bodies and x is heavier than y, then x will fall faster than y. This is not perfectly precise and is thus open to interpretation. It could be taken to apply to a case in which y has been falling for 1,000 feet and x is just starting from the ledge, and held to entail that x will fall 100 feet from 0 to 100 faster than y will fall 100 feet from 1,000 to 1,100. An experiment which proved that consequence is false would then refute (Faster) on that interpretation. That could be good quality experiment. It would be low quality interpretation. It is reasonable to so interpret (Faster) that, in a test, x and y must start from the same speed, preferably 0.

The first argument against (Faster) features three imaginary objects: a lighter, a heavier, and a combination of the two. The argument is that (Faster) entails that H+L falls fastest, but since L falls slower, it should resist the impulse of H in the combination so that H+L falls slower than H--- a contradiction held to follow from (Faster), thus refuting it. This can be put more clearly as interpreting (Faster) to mean that any heavier object falls faster than any lighter object even when the two objects are parts of one falling object. This ties Aristotle's name to a rule which entails that any body x must fall faster than any body y which is a proper part of x.

That interpretation of (Faster) deserves a place in Aristotle's list of sophistical refutations. The combination of heavier and lighter results in one object. (Faster) entails that if three objects, heavier, lighter and a duplicate of their combination are pushed from a ledge, combination will

fall faster than heavier or lighter and heavier will fall faster than lighter. It may be objected that heavier and lighter do not cease to be objects by being combined. The wheels of a falling automobile are still four objects. Very true, but in calculating the falling speed of the automobile the parts are not counted separately. That bodies which are attached fall at the same speed follows from the meaning of "attached". They must travel at the same speed to remain attached---unless we have to consider elasticity. A super elastic bungee cord may not save the jumper even if they are sophistically counted as "attached" to the bridge.

Frege warned about counting objects---one deck, 52 cards, etc. In dropping a deck of cards it is important to a fair assessment of (Faster) whether they are in the box and one falling body, or loose and 52. "The cards do not cease to be 52 objects when they are in the box!" Very true. But the (full) box is one falling body and its contents are not distinct falling bodies. Whether each separate card would fall as fast as the whole boxed deck is a crucial point at issue in the discussion. To insist that (Faster) entails that the full box must fall faster than each of the contained cards even when they are parts of the full box trivializes (Faster) so as to allow an a priori refutation, but not one showing excellence in reasoning.

4. A second argument has two identical weights of identical shape and size dropped simultaneously, side by side. (Faster) is not committed about objects of equal weight. It may seem plausible to assume the objects would fall side by side. Now we add the idea that the two weights are glued together, falling in the same pattern. We could use four duplicate weights, two glued together and two free. That is three falling bodies. (Faster) entails that glued would fall faster. The rebuttal says that there is no reason why glued should fall any faster than the two free.

That rebuttal begs the question. (Faster) clearly entails that glued will fall faster, and it gives a clear reason---glued is heavier than either free. It is one heavier falling body. I grant that this reason has been shown incorrect by experiments. But in this thought experiment it is not acceptable to simply insist there is no reason why glued should fall faster than the two side by side frees. Gluing produces one body of double the weight of the frees. True, it would not double the weight of the two objects

together on a scale. But the falling object is now one of double weight, which accelerates, which an object on a scale does not do. Nor do two objects on a scale, or 10 lbs. of loose sand. On a scale (which is not falling) the object is not a falling body. To say it is obvious, without experiment, that this makes no difference, simply denies (Faster).

5. A third line of argument is based on dropping lighter first, followed by heavier. (Faster) entails that heavier will overtake lighter if given sufficient distance to overcome the head start. Impact would depend on the shape and the line of fall, not to mention rigidity, mention of which would be foregone if this were the mechanics of rigid bodies. A cube of lead could have the same dimensions as one of wood and the line of fall, assuming, as required by (Faster) that heavier is falling faster, could bring two sides precisely together. With two spheres, impact would be point-like. If the lines of fall were merely parallel, contact would vary widely among cases. Staying with one line of fall, (Faster) entails collision and collision entails that the two speeds cannot remain constant throughout the impact, lighter gaining in speed and heavier losing. Such changes in speed are not inconsistent with (Faster) on a reasonable interpretation.

Now we can introduce a further specification. The objects are designed so that contact results in their immediately being conjoined. This can be arranged (imagined) in a variety of ways. Just one is with the two cube sides coinciding and being instantly glued. Perfect alignment might make this idealized gluing seem irrelevant to the result, if the upper part would press continually on the lower. That would not make it irrelevant to evaluating (Faster). Glue gives us one object---a crucial point. Hooks would require different lines of fall and would bring in twisting force, etc. In the simple case, the gluing impact immediately results in a combination, one object, which is heavier. (Faster) entails that new heavier (the combination) will immediately begin to fall at a greater rate than either old heavier or lighter would---assuming equal initial speed. This is held to be inconsistent with the change in speed in heavier and lighter due to their collision.

6. That does not follow. The fact that a collision slows up heavier and speeds up lighter is consistent with (Faster) on a fair interpretation. (Faster) means that if heavier and lighter are compared from the same initial speed, heavier will fall faster. The collision in the thought experiment slows heavier and speeds up lighter. Proper comparison between the three objects requires they all start from the same initial speed. Being slowed or sped up by impact cannot be counted without this consideration. If lighter is struck by anything that increases its rate of fall, (Faster) does not entail that heavier will overcome this advantage immediately.

A good test could have duplicates of heavier and lighter falling separately. Then (Faster) entails or is at least fairly most consistent with, heavier2 passing lighter 2 exactly when glued is formed by the collision of heavier1 with lighter2. Now a proper comparison requires considering the speed of glued at its formation. (Faster) requires that glued will outpace both heavier and lighter in their falls--- if they all start from that same speed. This is compatible with any other consequences of (Faster) that have been established in this argument.

7. Thus I conclude that none of the scenarios described in the above thought experiments proves that (Faster), fairly interpreted, entails a contradiction. The refutation of (Faster) is primarily a task for well-designed and performed experiment. Of course, the interpretation of experiment requires applying some principles accepted independently of the experiment. And the task of explaining why objects made of different materials fall at the same rate in the absence of resistance from air, water or some other medium, is not settled merely by experiment. My conclusion is just that the three arguments above either misrepresent (Faster) or beg the question. Additionally, I add the contingent claim that those arguments are presented in popular summaries as a priori or logical refutations of (Faster). They are sometimes presented as paradigms of such refutation. That is not a good contribution to logic teaching.

The arguments just discussed undoubtedly are connected to important ideas in the history of science. It may be found objectionable to examine them with no effort to trace these connections. I would gladly

concede that the historical connections constitute the more important study. It is bad to present a clear and simple argument as representing a historical debate which is in fact far more complex. This is a fault which can cast an unfortunate shadow over logical analysis. The three arguments above are clear, simple, and bad. They fail to fairly interpret (Faster). Establishing this does not require any account of the relation between the physical scientific views of Aristotle or Galileo. Detailed construction of such accounts is a valuable enterprise. It is unfortunate if it distracts us from the clear and simple defects of the allegedly a priori refutations of (Faster).[2]

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[2] The editors would like to thank Maria Gaţe for assistance in tracking the entries in the bibliography for this article.

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