# Heidegger and Galileo's Slippery Slope

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*ABSTRACT: In* Die Frage nach dem Ding*, Martin Heidegger characterizes Galileo as an important transitional figure in the struggle to replace the Aristotelian conception of nature with that of Newton. However, Heidegger only attends to Galileo's modernity and not to those Aristotelian elements still discernible in Galileo's work. This article fleshes out both aspects in Galileo in light of Heidegger's discussion. It concludes by arguing that the lacuna in Heidegger's account of Galileo is the consequence of Heidegger's own self-conscious modernity − a modernity that he slyly hints at in a remark he makes in FD concerning Galileo and Democritus.*

*RÉSUMÉ : Dans* Die Frage nach dem Ding*, Martin Heidegger qualifie Galilée de figure importante dans la lutte pour remplacer la conception aristotélicienne de la nature par celle de Newton. Toutefois, Heidegger examine seulement les traits modernes de Galilée et non ceux qui ressemblent à Aristote. Cet article précise ces deux aspects à partir de la discussion dans* Die Frage nach dem Ding*. Il conclut par l'affirmation que la lacune dans le portrait de Galilée est la conséquence de la modernité consciente de Heidegger lui-même — une modernité à laquelle il fait allusion dans une remarque concernant Galilée et Démocrite.*

## Introduction

This essay is concerned with Martin Heidegger's account in *Die Frage nach dem Ding* of Galileo's role within the movement from an Aristotelian to a Newtonian conception of nature. For Heidegger, Galileo is a transitional figure in the long controversy that was required to effect this revolution within physics. However, in FD and elsewhere, Heidegger focuses on Galileo's modern aspects, and pays scant attention to those elements of Aristotelian thought that are still evident in Galileo's work. In what follows, I outline Heidegger's

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account of the rise of mathematical projection in modern science, paying particular attention to the role Galileo plays in that movement and supplementing Heidegger's account with evidence that Galileo continued to use Aristotelian concepts and methodologies even while he pioneered the new approach that would ultimately eclipse Aristotelian science. I conclude by proposing that it is a very modern hermeneutics that leads Heidegger to "skip over" traces of ancient thought in Galileo, and that Heidegger himself offers us hints that he knows as much.

## 1. Modern science and mathematics

In the preface to the second edition of the *Critique of Pure Reason*, Kant credits Galileo *inter alia* with teaching the students of nature the mathematical lesson "that reason has insight only into that which it produces after a plan of its own" (B xiii), the very same lesson that inspired Kant's Copernican revolution in philosophy. Heidegger takes up the example of Galileo in a key FD section, "Die neuzeitliche matematische Naturwissenschaft und die Entstehung einer Kritik der Reinen Vernunft," in the context of a discussion contrasting modern science with its ancient and medieval counterparts.

Heidegger begins by considering and ultimately rejecting three candidate differentia between modern and ancient science: (1) modern science's emphasis on facts over concepts, (2) its use of experiments, and (3) its calculative nature. Despite positivistic scientists' privileging of the ontic over the ontological – that is, of facts over concepts – Heidegger argues that this is only the "indolence" (FD, p. 51 / MSMM, p. 248) of scientific assistants and technicians, and that such indolence has always existed within the lower echelons of scientific culture. Today, as ever, the truly great scientific minds – Heidegger names Heisenberg and Bohr as examples – reveal their greatness precisely in their genuinely philosophical thinking, in their willingness to linger with that which is questionable. The very best science has never ceased to regard itself as natural philosophy. Thus, both facts and concepts play roles in both ancient and modern science. Heidegger likewise rejects the view that modern science's uniqueness lies in its use of experiment or measurement. Ancient and medieval scientists were well-versed in experimentation, in the sense of testing the behaviour of things for the purpose of ordering them. And, while modern science is indeed marked by measurement and calculation, so too was the science of the ancients. Thomas Kuhn notes the sophistication of the mathematical calculations that supported Ptolemaic geo-centrism. It was not until sixty years after the death of Copernicus that Kepler was finally able to furnish an adequate mathematical formalization of the heliocentric theory. Until that time, the calculations and measurements of ancient astronomy were markedly superior to those of its modern challenger (Kuhn, p. 376).

So, while modern science may indeed, in some manner, privilege facts, and while it is certainly experimental and calculative, none of these aspects captures the distinct essence of modern science. As Heidegger puts it, "With these

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three characteristics of modern science, that it is a factual, experimental, measuring science, we still miss the fundamental characteristic of modern science" (FD, p. 52 / MSMM, p. 249). This characteristic, Heidegger argues, lies in the origin of modern science's store of facts and concepts; in its manner and intent in setting up experiments; and in the way in which its measurements and calculations are carried out. That is, "the fundamental feature must consist in what rules and determines the basic movement of science itself. This characteristic is the manner of working with the things and the metaphysical projection of the thingness of the things" (FD, p. 52 / MSMM, p. 249).

For Heidegger, this decisive feature of modern science is its *mathematical* nature. However, Heidegger's account of the mathematical is surprising. Clearly, given his earlier assertions, he cannot identify the mathematical with calculation and measurement *tout court*. Instead, he looks back to the Greek concept of *ta mathēmata*, or learning, for his understanding of mathematics. For Heidegger, *ta mathēmata* is "an extremely peculiar taking ... where he who takes only takes what he basically already has" (FD, p. 56 / MSMM, p. 251). *Ta mathēmata* engages things in terms of "what we already know them to be in advance, the body as the bodily, the plant-like of the plant ... and so on" (FD, p. 56 / MSMM, p. 251). The mathematical is, therefore, an understanding that we get out of things only inasmuch as we bring this understanding with us to begin with. This is the sense of learning as recollection that we find in the *Meno*. For Heidegger, mathematics in the narrower sense – that is, the discipline of mathematics – is paradigmatically mathematical in this broader sense since numbers themselves are always conceptually prior to the particular collections they denote. Thus, "we see three chairs and say that there are three. What 'three' is the three chairs do not tell us, nor three apples, three cats, nor any other three things. Rather, we can count three things only if we already know 'three'" (FD, p. 57 / MSMM, p. 252). Heidegger follows Plato in arguing that "the fundamental condition for the proper possibility of knowing is the knowledge of the fundamental presuppositions of all knowledge and the position we take based on such knowledge" (FD, p. 58 / MSMM, p. 254). Thus, the mathematical, in this broadest sense of questioning what is already familiar, is the foundation of all academic work, work with which we will never be through "as long as we take ourselves seriously" (FD, p. 58 / MSMM, p. 254).

So, when Heidegger argues that modern science is characterized by mathematicity, then on one level he might be regarded as simply asserting the hermeneutical structure of understanding within the sciences. In modern scientific understanding, as in all understanding, the human being as *Dasein* brings a fore-understanding that she projects upon the world, ineluctably transforming the *present-at-hand* to the *ready-to-hand* in the very act of encountering it. In science as elsewhere, *Dasein* is always getting ahead of itself. This is no less true of ancient than it is of modern science. However, for Heidegger, there is clearly an important difference between modern and ancient science. If we are to locate the unique essence of modern science in its mathematicity, some

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further understanding of the scientific encounter with things as *ta mathēmata* is still needed. In order to reach such an understanding, Heidegger considers the genesis of the concept of inertia.

## 2. Aristotle and Newton

Newton's First Law of Motion reads "Every body perseveres in its state of being at rest or of moving uniformly straight forward, except insofar as it is compelled to change its state by forces impressed" (p. 416). This law was rapidly and unanimously adopted by the scientific community of the day, and continues today to be accepted as self-evident. However, Heidegger argues that inertia is a principle that would have been unintelligible in the centuries leading up to Newton's physics.

Prior to Newton, physics was dominated by Aristotle. For Aristotle, insofar as bodies manifest themselves as *physis* or nature, they are in motion. Motion for Aristotle, however, is both broader and more specific than Newtonian motion. On the one hand, "motion, in general, is *metabolē*, the alteration of something into something else" (FD, p. 64 / MSMM, p. 260). Thus, bodies move not only when they change positions from one place to another, but also when they come to be or cease to be, when they grow or decay. The rising blush on a face is, in this sense, a movement, as is the metamorphosis of a larva to a pupa to a butterfly. On this view, for a thing to move – in any sense of that word – is for it to express itself in accordance with its entelechy.

Against this broad understanding of motion, however, Aristotle also maintains a more specific understanding of *proper* motion – that is, of the type of movement that is proper to particular types of things, and to particular places. Thus, the motion that is proper to Earth is downward; the motion proper to fire is upward. These are the motions that are natural for these bodies. The force, or *dynamis*, of this motion has its origin in the body itself. If one uses a force external to the body to prevent that body's manifesting its natural motion, this for Aristotle is violence, or *bia*. Throwing a rock into the air with a sling is a violent (*biai*) movement inasmuch as it violates the rock's natural movement toward the Earth. Similarly, Aristotle identifies natural and violent movements with the places in which those movements occur. The natural vector for a terrestrial movement (whether up or down) is rectilinear. Only a violent force could therefore move a body in the terrestrial plane in anything other than a straight line. In contrast with this, the proper celestial movement is a circular movement around the centre. Rectilinear and circular motion are the two simple types of motion; the third and *mixed* type of motion is some combination of these two. Thus, fire naturally moves in a straight line away from the Earth and then, upon reaching the heavens, assumes the circular movement that is natural to that place. For Aristotle, the province of physics is bodies in their natural states. The scientist learns about these bodies and of their proper *dynamis* by attending to their natural motions, in the broad sense of *metabolē*. Violent motions, insofar as they conceal the natural *dynamis* of bodies, do not tell us

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anything about those bodies. In a sense, they obscure the very bodies that are the subject of physics. For this reason, Aristotle rarely discusses violent motions (Drake 1989, pp. 7-8, 52).

It should be clear by now that Newton's first law represents a radical departure from the Aristotelian account. This is perhaps most obvious in its replacement of *intrinsic* with *extrinsic* force. Where Aristotle regards natural motion as *impetus*, motion deriving from the internal *dynamis* of the body, Newton adopts a mechanistic account in which motions have their origins outside of bodies. Where, for Aristotle, each being has an entelechy through which it expresses in its own distinct motion, for Newton, bodies are indifferent billiard balls awaiting an external force to bring them into motion, or to arrest their motion. With his articulation of a universal law governing the motion of all bodies, Newton effects a figure-ground reversal in physics. It is no longer individual entelechies to which scientists must attend, but rather the manifestation of universal law. After Newton, when scientists observe the motions of individual bodies, they do so only as a means to identifying and explaining universal regularities. The particular body's role in science becomes secondary. That which, on the Aristotelian account, was the main actor of physics, now plays a bit part.[1] Similarly, in his privileging of locomotion over *metabolē*, Newton radically revises the notion of place to entail coordinates within a space-time matrix. It no longer matters where a motion occurs; the very same equation applies to it everywhere. As Heidegger puts it, "Each body can in principle be in any place. The concept of place itself is changed: place no longer is where the body belongs according to its inner nature, but only a position in relation to other positions" (FD, p. 67 / MSMM, p. 263). As a consequence of this, motion is seen as a mere change of relative position, fully explicable in terms of the measurement of distances. Thus, Newton's first law doubly – that is, both in the reduction of particular bodies and in the reduction of particular places – reduces the real to a mathematical variable. In a sense, science after Newton is no longer concerned with *what* things are, or with *where* they are.

It is for this reason that Heidegger argues that Newton's first law of motion would have been unintelligible to both the ancients and the medievals, and that "In its discovery and its establishment as the fundamental law lies a revolution that belongs to the greatest in human thought" (FD, p. 61 / MSMM, pp. 256-57). In a sense, when ancient and medieval science become modern – that is, when they become Newtonian – science ceases to be a phenomenological practice.[2] This is precisely the unique essence of modern scientific mathematicity that we have been seeking. Before Newton, the fore-understanding that the scientist brought to his understanding of nature included an interest in individual entities and, hence, a hermeneutical openness to Being; after Newton, the scientist's hermeneutical horizon is restricted by the fore-understanding that individual entities are the indifferent manifestations of universal laws. Within this horizon, it is no longer possible for science to attend to things as individuals. Thus, as Lawrence Cahoone observes, what is essential and most

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problematic about modern science for Heidegger is not its mathematical character or its apriorism in general, but its " 'conceptual' … cast of apriorism, which makes logical categories or 'transcendental concepts' logically prior to the encounter with entities" (p. 18).

On Heidegger's view, what is most revolutionary about the Newtonian turn in science and its accompanying conceptual apriorism is its demotion and eventual banishment of bodies from physics. This banishment is immediately evident in the failure of Newton's First Law to refer to real objects in the world. The principle of inertia concerns bodies left to themselves, bodies upon which no force is impressed. However, this is an idealization. There simply are no such bodies. Thus, for Heidegger, the foundational law of classical physics concerns non-bodies, non-entities. Where did the bodies go? How and when were they banished from physics? According to Heidegger, this movement, for which Newton's articulation of the First Law of Motion was the culmination, was not a sudden turn, but rather "required a long controversy to bring it into power" (FD, p. 69 / MSMM, pp. 265-66). He argues that Galileo played a decisive role in this battle, both in his a prioristic projection within empirical practice and in his thought experiments involving impossible objects.

## 3. Galileo

Heidegger particularly locates Galileo's mathematical projection in the latter's famous free fall experiment. In the Aristotelian physics of the Middle Ages, it was a commonplace that heavy bodies fall more quickly than light bodies since it is in the nature of the former to move in a straight line toward the Earth, whereas it is in the nature of the latter to move upwards. While a young mathematics professor at Pisa, Galileo challenged this convention with his intuition that all bodies, impressed by the same force, accelerate at the same rate. To prove his hypothesis, Galileo (so the story goes) dropped objects of various weights from the top of the Tower of Pisa and timed their descents. In practice, though, the free fall acceleration rates of the objects varied, and Galileo was obliged to offer ad hoc explanations of the discrepancies in terms of wind resistance and so on. Thus, while witnesses to the experiment saw evidence in favour of the Aristotelian account, Galileo was able to tweak his predictions and his results in order to support his initial anti-Aristotelian hypothesis. As Heidegger puts it: "Both Galileo and his opponents saw the same 'fact.' But they interpreted the same fact differently and made the same happening visible to themselves in different ways" (FD, p. 70 / MSMM, p. 266). On Heidegger's account, widespread rejection of his free fall results ultimately obliged Galileo to give up his Pisan professorship.

Despite the confidence with which Heidegger discusses the free fall experiment and its reception, it is not clear whether Galileo ever actually dropped weights from the Tower of Pisa. He certainly makes mention of similar experiments in *De Motu* (see pp. 31 n.12, 106 n.2 and 107), which he composed

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between 1589 and 1592 during his time as a mathematics professor at the University of Pisa. Moreover, as Trish Glazebrook points out, several of Galileo's contemporaries dropped bodies of different weights from heights. Among these, Renieri dropped weights from the Tower of Pisa, an experiment about which he corresponded with Galileo some years after the composition of *De Motu* (Glazebrook 2000, pp. 73-74). In his description of his experimental results, Galileo maintained that, when first dropped, light bodies fall more quickly than heavy bodies (*De Motu*, pp. 106-110). Glazebrook argues that this "is so unexpected a claim that presumably its source must be observation" (Glazebrook 2000, p. 73). This is confirmed by Rice University's Galileo Project, which reports that performing the free fall experiment produces exactly the results Galileo described.[3] It requires more force to hold a heavy iron ball in the hand with the palm turned downward than to hold a wooden ball in this way. Thus, experimenters release the heavier balls slightly later than they do the wooden ones, creating the illusion that wooden balls at first fall more quickly than iron ones.

Whether the image of Galileo dropping weights off the Tower of Pisa is the stuff of history or of legend, Heidegger nowhere expresses any doubt that it happened. Indeed, his description in FD of witnesses' reactions to the experiment is so vivid that it suggests an eye-witness account: "The witnesses to this experiment," Heidegger writes, "became really perplexed by the experiment and Galileo's upholding his view" (FD, pp. 69-70 / MSMM, p. 266.) Heidegger has a dual purpose in offering this account. His aim is both to emphasize sixteenth-century resistance to the free fall experiment and thus to represent it as an important turning point between scientific epochs and also, by contrasting Galileo's confidence in his theory against the perplexity of the Pisans, to evince the conceptual apriorism that characterized Galileo's empiricism. It is worth considering each of these elements in turn.

### *3.1. Crucial experiments*

Despite the fact that Heidegger takes Galileo's free fall experiment as a dramatic turning point for the shift in physics from Aristotelianism to mechanism – Trish Glazebrook wryly describes it as "the Galilean founding myth of modern science" (Glazebrook 2000, p. 75) – he is clear that at the time it was performed, its results were widely rejected. What to us now appears self-evident was at first, it seems, not evident in the least. What the free fall experiment did not do, then, was to provide a single decisive result that forced all observers to accept a single theory. It was not, that is, a crucial experiment.

Paradigmatically, a crucial experiment is one capable of producing a single datum in itself sufficient to adjudicate between two competing theories. Heidegger's description of Galileo's ad hoc adjustments and of the poor reception the experiment received within the scientific community would seem to align

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him with the rejection of crucial experiments by such figures as Duhem, Quine, and Kuhn. On Heidegger's account, "The witnesses to this experiment ... became really perplexed by the experiment and Galileo's upholding his view. They persisted the more obstinately in their former view" (FD, p. 70 / MSMM, p. 266). Despite its mythic status, the free fall experiment does not establish Galileo's hypothesis.

Rather, in a sense, Galileo's hypothesis skips over the experiment altogether. Inasmuch as the results of Galileo's experiment are determined by the axioms of his system,[4] neither the particular results nor, arguably, the particular experiment is necessary. The experiment is no longer experience, in the sense of "taking in and studying of what shows itself" (FD, p. 72 / MSMM, p. 269). Rather, the modern experiment, as exemplified by Galileo, "poses conditions in advance to which nature must answer in one way or another" (FD, p. 72 / MSMM, p. 269).

That the mathematically projected experiment of modern science simply cannot yield the surprising result that is the hallmark of the crucial experiment becomes even clearer in light of Heidegger's distinction in "The Age of the World Picture" between the *empeiria* of Greek science and the experimentation of modern research. Heidegger characterizes *empeiria* as "the observation of things themselves, their qualities and modifications under changing conditions, and consequently the knowledge of the way in which things as a rule behave" (ZW, p. 74 / AWP, p. 121).[5] In contrast, modern experiment, he argues, "begins with the laying down of a law as a basis" (ZW, p. 74 / AWP, p. 121). This law derives from a perceived "ground plan" of nature. That is, hypotheses are generated not by acts of imagination or creativity, but rather mathematically from axioms of the system of research: "That ground plan furnishes a criterion and constrains the anticipatory representing of the conditions [of the experiment]" (ZW, p. 74 / AWP, p. 121).

Peter Machamer agrees that, for Galileo, a priori explanation was prior to empirical demonstration: "[Experiments] were not merely rhetorical devices invoked to convince others about the certainty of conclusions, they were also epistemic requirements necessary to give the proper experience to the individual scientist putting forward the explanation" (p. 68). Indeed, Galileo's observation in the *Two New Sciences* that it is "usual and necessary" for scientists to "confirm their principles with sensory experiences that are the foundations of all the resulting structures" (*Two New Sciences,* p. 169) makes explicit both that scientists' theoretical principles are prior to their empirical results and also that these doubly *a posteriori* results further determine all future experimentation. Machamer observes that, due to his practical training in the mechanical arts, Galileo treated his experiments just as he treated his mechanical models – that is, as purposeful constructions with intended results (p. 68). As a consequence, what emerges in a Galilean experiment is always *technē*, never *physis*. It is the role of the scientist to calculate nature before encountering it. Despite the myth of the crucial experiment, the modern experiment is intended not to

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produce astonishing results, but rather to confirm what the scientist has known all along.

Indeed, the free fall experiment confirmed what was known all along not only for Galileo himself but for the witnesses to the experiment who "persisted the more obstinately in their former [Aristotelian] view" (FD, p. 70 / MSMM, p. 266) after observing the experiment. Heidegger is clear that the interpretation of experimental results is theory-laden for both sides. There would seem to be two obstacles, then, to regarding the free fall experiment as a crucial experiment – Galileo's mathematical approach to the experiment and the failure of the free fall experiment to persuade Galileo's opponents. But then, why does Heidegger present this experiment as a turning point in the shift between scientific epochs?

While Heidegger's account clearly creates some difficulties for naïve proponents of crucial experiments, Glazebrook doesn't regard him as rejecting crucial experiments. She cites evidence from the *Beiträge* that Heidegger held both "the weaker claim that [crucial] experiments exist, but also the stronger claim that their possibility in principle is a condition for the modern scientific method" (Glazebrook 2000, p. 76). Moreover, she argues that Heidegger's engagement of crucial experiments helps to resolve a seeming paradox about them that has dogged analytic philosophy of science: on the one hand, in crucial experiments a single result is taken as decisive, but on the other hand, even proponents of crucial experiments regard repeatability as a criterion of experimental success. If one set of results is enough, then why should any repetition of those results be desirable? Glazebrook argues that Heidegger's emphasis on the ideology of science, as contrasted with analytic philosophers' emphasis on the epistemology of science, reveals repeatability and decisiveness of a single result to be two sides of the realist coin (Glazebrook 2000, p. 76). For the modern scientist engaging nature mathematically, the locus of the real is not essences but individuals. Thus, the mathematical engagement of a single individual is sufficient to be decisive. A crucial experiment gets repeated not because it is indecisive without repetition, but "*precisely because its nature [is] already recognized* and resisted" (Glazebrook 2000, p. 81, italics in the original) . If the free fall experiment had not been a devastating blow for the proponents of the older physics, then performing the experiment would not have jeopardized Galileo's Pisan professorship.

Heidegger's point in emphasizing the resistance to the free fall experiment is precisely to evince the major shift occasioned by the experiment. But the shift lies not in the results of the experiment – this is why Heidegger's account is unaffected by the fact that the results of the experiment were not decisive for Galileo or his opponents – but in its method. Writes Glazebrook: "… more than a theory is thrown over by the toss from the tower. A cosmology falls. And, more significantly, a new way of doing science supplants previous methodologies. Galileo's freefall experiment is *methodologically* crucial" (Glazebrook 2000, p. 83).

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### *3.2. Galileo's a priorism: slippery slopes and rough planes*

According to the founding myth about the free fall experiment, the new methodology that it (crucially) introduces is physics as mathematical projection. Galileo undertook his free fall experiment with a particular result already in mind – a result dictated by his conception of the uniformity of nature. He was so committed to this result and to this conception that he was willing to make ad hoc adjustments to his data in order to salvage his hypothesis when his initial results failed to substantiate his predictions. Thus, Heidegger argues that "… *against* the evidence of experience, Galileo upheld his proposition" (FD, p. 69 / MSMM, p. 266).

Perhaps this was how it went with the free fall experiment. However, Heidegger does not confine himself to discussing this experiment. In FD and in a 1916 lecture, "Der Zeitbegriff in der Geschichtswissenschaft" (ZG), Heidegger takes up two different examples that are meant to illustrate Galileo's mathematical way of thinking.

The example that Heidegger examines in ZG is Galileo's discovery of the times squared law (or "law of fall"). The times-squared law concerns the rate of acceleration for falling objects (or for those rolled down an inclined plane). It states that the distance that a falling body travels is directly proportional to the square of the elapsed time. Heidegger characterizes Galileo's discovery of the law as an instance of the "strangely new accomplishment" (ZG, p. 361 / CTSH, p. 52) whereby Galileo arrives at laws. According to Heidegger, "Galileo did not begin with the observation of individual instances of the appearance of gravity but rather with a general assumption (hypothesis) that runs: Bodies – having lost their support – fall in such a way that their velocity increases in proportion to time ($v = g \cdot t$)" (ZG, p. 361 / CTSH, p. 52). Heidegger proceeds step-by-step through Galileo's derivation of the times-squared law from this initial assumption "in order to demonstrate that nowhere in the whole examination was there talk of this or that particular body, this or that duration of time, this or that space of a falling body" (ZG, pp. 361-62 / CTSH, p. 52).

Now, it is true that *Heidegger* goes through the proof without ever mentioning particular bodies, etc., but it is important to note that this is not how Galileo reports the discovery. Rather, his discussion of the times-squared law in *Two New Sciences* includes careful description of the materials he used in his experiment:

> A piece of wooden moulding or scantling, about 12 cubits long, half a cubit wide, and three finger-breadths thick, was taken; on its edge was cut a channel a little more than one finger in breadth; having made this groove very straight, smooth, and polished, and having lined it with parchment, also as smooth and polished as possible, we rolled along it a hard, smooth, and very round bronze ball. Having placed this board in a sloping position, by raising one end some one or two cubits above the other, we rolled the ball, as I was just saying, along the channel, noting, in a manner presently to be described, the time required to make the descent. (p. 178)

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To be fair, this description accords with Kant's characterization of Galileo as causing "balls, the weights of which he had himself previously determined, to roll down an inclined plane," and thereby constraining nature to answer questions of reason's own determining (B xiii). And, it is worth recalling, this account in Kant to a great degree animates Heidegger's discussions of Galileo. However, Heidegger's explanation in ZG is nonetheless misleading in implying that Galileo himself presented the times-squared law as a mathematical proof and not as an actual experiment. The only reference that Heidegger makes in ZG to Galileo's actually performing the experiment described above is a brief one intended to cast Galileo's scientific method as hypothetico-deductive: "Galileo tested this equation against concrete instances, and it was confirmed by them. Thus, the above assumption, from which the law was obtained in a purely deductive manner and subsequently experimentally confirmed, is valid" (ZG, p. 361 / CTSH, p. 52).

However, any characterization of Galileo's method as hypothetico-deductive must be regarded as questionable given the experimental work that culminated in the law of fall. According to Stillman Drake, the fact that Galileo actually performed experiments like the one described above with inclined planes hastened his discovery of the times-squared law. Here, according to Drake, is how the earliest instance of these experiments went: Galileo began by rolling a ball down a plane while steadily counting time. Once the first unit of time had elapsed,[6] he carefully marked the place on the ramp occupied by the ball at that moment. This became a standard unit of measurement. He proceeded to mark these units on the plane with a series of tightly stretched strings. The strings meant that the ball's subsequent passage over each unit of measurement was slightly audible. With this apparatus in place, Galileo discovered that the ball traversed one standard unit of length in the first beat, three more in the next beat for a total of four, five more in the next for a total of nine, seven more in the next for a total of sixteen, and so on. Thus, the ratio of elapsed time to the total distance travelled was 1:1, 2:4, 3:9, 4:16; ...[7]

According to Drake, the times-squared law would not have been obvious using painstaking standardized measurements. The mathematical formula that emerged from a unit of length derived from a counted beat would not have been apparent with millimetres and seconds. As Drake observes,

> If one were to measure in fractions of an inch, applying a yardstick instead of a length of string, this odd-number spacing might go unnoticed and the law would not become evident. The unit used makes no difference mathematically, but could greatly increase the difficulty of discovery. (Drake 1989, pp. 1-2)

Thus, while the times-squared law could only with difficulty be derived a priori from mathematics,[8] Galileo stumbled upon it with comparative ease using rough, intuitive measurements. The only way to discover the times-squared law was to attend to the relevant phenomena without prejudice. Once Galileo

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had confirmed the law through repeated trials, it was a simple matter to venture and test the hypothesis that the times-squared law applied not only to movement on an inclined plane, but also to objects in free fall. Thus, while the free fall experiments were indeed posterior to Galileo's articulation of a universal law, the law itself was one he had discovered in an experiment that precluded mathematical projection.

So it is that, while on the one hand Galileo's opponents could maintain the position that rate of fall is contingent upon a body's weight only against the evidence of experience, Galileo's discovery of the law of fall was ultimately rendered possible because his investigation more closely resembled *empeiria* than it did the modern research experiment. According to William Wallace, toward the end of his life Galileo described himself as a true follower of Aristotle, and, in matters logical, as a life-long Aristotelian. Wallace locates this Aristotelianism not in Galileo's conclusions in the physical sciences but in his logical methodology in his scientific work (p. 51). Galileo's empirical work leading up to the law of fall goes some way toward explaining Galileo's claim.

I said above that Heidegger gives a different example of Heidegger's a prioriism in FD. This example is Galileo's thought experiment of a projectile on a horizontal plane. Heidegger writes that the proposition at issue in the thought experiment "may be considered the antecedent of the First Law of Newton" (FD, p. 70 / MSMM, p. 267). And indeed, both Huygens and Newton himself credited Galileo with the discovery of inertia (Reitan, p. 83).[9] Heidegger quotes the following passage from Galileo's *Two New Sciences*: "I think of a body thrown on a horizontal plane and every obstacle excluded. This results in what has been given a detailed account in another place, that the motion of the body over this plane would be uniform and perpetual if the plane were extended infinitely" (Qtd. FD, p. 70 / MSMM, p. 267).[10]

In his interpretation of this passage, Heidegger writes that "what Galileo thought in advance about motion was the determination that the motion of every body is uniform and rectilinear, when every obstacle is excluded, but that it also changes uniformly when an equal force affects it" (FD, p. 70 / MSMM, p. 266). Like Newton, Galileo premises his account on the imagination of impossible objects – a frictionless body and an infinitely extended plane. Thus, he clearly presages the Newtonian banishment of particular bodies that Heidegger identifies. Despite this, however, it is important to observe that Galileo is not generally credited with the discovery of inertia since inertial mechanics are solely concerned with extrinsic force and Galileo retained an Aristotelian notion of impetus or intrinsic force. Thus, he is responsible for a "pre-inertial framework" but not for the concept of inertia (Hooper, pp. 147, 171).

Eric Reitan rejects the view that Galilean physics marks a decisive turn away from the Aristotelian concept of nature. He argues that Galileo inherited from Albert the Great a conception of nature as the motion and rest "of that in which it is primarily and essentially and not accidentally (or incidentally)" (Reitan, p. 92). According to Reitan, Galileo retained the ancient distinction between

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the place that is proper to a thing (Albert likens this to the habitat that is proper to an animal) and the space that is indifferent to the things in it. Thus, unlike Newton, for whom bodies have locations but not places and for whom the cause of motion or rest is extrinsic to the thing that moves, Galileo regarded a thing's nature as dictating its proper place and proper motion.[11] For Reitan, Galileo's modern scientific advances were themselves the product of his Aristotelian heritage. He writes that "Galileo's inertial concepts, which enable him to rotate the earth, are founded on an Aristotelian understanding of nature as a principle of motion and rest" (p. 85).

Galileo reveals his Aristotelian commitment to the notion of proper motion in a discussion in *De Motu* concerning whether motion along a horizontal plane is natural or violent. Juxtaposing motion down an inclined plane, which Galileo describes as "natural" and which, on his view, requires no force, and motion up an inclined plane, which goes against natural movement and is therefore "forced,"[12] Galileo imagines a body travelling along a perfectly smooth horizontal plane and questions whether any force is required for its movement. He deduces that if motion up the smallest possible inclination requires the smallest possible force, then motion up a zero inclination – that is, along a horizontal plane – must require less than the smallest possible force, which is to say, no force at all. And so, "on the horizontal plane itself the motion of the body is neither natural nor forced" (*De Motu*, p. 66). Drabkin regards this conclusion as "a step toward the elimination of the dichotomy of natural and forced motion, a step ultimately toward the inertial concept" (*De Motu*, p. 66 n.7). While this may well be the case historically, Reitan regards Galileo as here attempting not to dissolve the Aristotelian dichotomy but to expand it into a trichotomy of natural, forced, and neutral motion. A marginal note by Galileo seems to support this thesis:

> From this it follows that mixed motion does not exist. For since the forced motion of heavy bodies is away from the center, and their natural motion toward the center, a motion which is partly upward and partly downward cannot be compounded from these two; unless perhaps we should say that such a mixed motion is that which takes place on the circumference of a circle around the center of the universe. But such motion will be better described as 'neutral' than as 'mixed.' For 'mixed' partakes of both [natural and forced], 'neutral' of neither. (*De Motu*, p. 67 n.9)

While Galileo's rejection of mixed motion is clearly a criticism of Aristotelian mechanics, his discussion of natural motion and his ascription of circular motion as proper to the circumference of the universe are both strongly indebted to Aristotle. Indeed, Heidegger's description of Aristotelian *bia* is equally well suited to Galileo's forced motion: "A motion contrary to nature, i.e., violent motion, has its cause in the force that affects it" (FD, p. 66 / MSMM, pp. 261-62). For Galileo as for Aristotle, the concept of force is required to explain only unnatural motions, not natural ones.

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Despite this Aristotelian cast to Galileo's thought, it is clear that even as early as *De Motu*, Galileo had already, like Newton, diminished the role and importance of individual bodies within physics. The earlier proto-inertial thought experiment, like the one later discussed in the *Two New Sciences*, concerned not real bodies in the world but idealized bodies – in fact, impossible bodies. Galileo is explicit:

> But this proof must be understood on the assumption that there is no accidental resistance (occasioned by roughness of the moving body or of the inclined plane, or by the shape of the body). We must assume that the plane is, so to speak, incorporeal or, at least, that it is very carefully smoothed and perfectly hard…. And the moving body must be [assumed to be] perfectly smooth, of a shape that does not resist motion, e.g., a perfectly spherical shape, and of the hardest material or else a fluid like water. (*De Motu*, p. 65)

Whereas the apparatus of Galileo's 1604 times-squared discovery were rough, ready, and real, this plane is "incorporeal," this projectile "perfect." The objects in this representation are not natural objects behaving in accordance with their entelechies, but mental objects carefully constructed to ensure certain mathematically projected results. Here, *empeiria* is eclipsed by research. The experiment skips over the thing.

## 4. Conclusion

Heidegger argues that the "fundamental conception" at the heart of modern science "is neither arbitrary nor self-evident. Therefore, it required a long controversy to bring it into power. It required a change in the mode of approach to things along with the achievement of a new manner of thought" (FD, p. 69 / MSMM, pp. 265-66). In Galileo's early discovery of the times-squared law and in his *De Motu* work on motions on inclined planes, we find both an Aristotelian openness to individual entities' proper motions as well as a Newtonian conceptual a priorism that banishes particular bodies. Galileo is thus not only a leader in the new mathematical conception of nature, but himself a properly transitional figure. Situated as he is upon the boundary of two epochs, he is a citizen of neither and both. Indeed, it is in Galileo's very ambivalence that the difficult transition from Aristotelian to Newtonian science can best be seen.

In *Die Frage nach dem Ding*, Heidegger observes that "Modern thought does not appear all at once. Its beginnings stir during the later Scholasticism of the fifteenth century; the sixteenth century brings sudden advances as well as setbacks; but it is only during the seventeenth century that the decisive clarifications and foundations are accomplished" (FD, p. 59 / MSMM, p. 255). It is instructive that Heidegger's discussion of Galileo in FD cites both his sixteenth-century free fall experiment and one of his seventeenth-century thought experiments. It would seem that, on Heidegger's view, Galileo deserves

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credit for both advances and setbacks, as well as for decisive clarifications and foundations in the development of modern thought. And, indeed, based on the evidence we've looked at in the pages above, this seems exactly right. Moreover, that Heidegger discusses Aristotle, Galileo, and Newton in the course of adumbrating the long controversy that was required to effect the revolution in physics shows that he regards Galileo as an importantly transitional figure – that is, a figure with feet in both the ancient and the modern camps. Given this, why does he provide evidence only of the modern elements in Galileo's thought and research, and skip over the abundant evidence of his affinities with Aristotle?

The surprising answer to this is, I think, quite simply that (whatever his affection for the ancient Greeks) Heidegger is himself a modern thinker, more Newtonian than he is Aristotelian or Galilean. That is, for Heidegger as for Newton, learning is *ta mathēmata*, the kind of engagement of things that takes out of them what we put into them to begin with. Since, in his discussion of Galileo in FD, Heidegger is seeking to explain the scientific movement into modernity, all that he sees in Galileo is his modern elements. That is, Heidegger himself brings modernity to his FD engagement of Galileo. In the same way that Galileo's interpretation of the results of his free fall experiment skip over the results themselves, and indeed in much the way that Newton's laws of motion skip over the particular bodies governed by those laws, Heidegger skips over the vestiges of ancient science in Galileo's thought.

This accords with Cahoone's argument that Heidegger rejects conceptual a priorism while nonetheless embracing existential a priorism:

> It is the nature of *Dasein* to project the world-horizon within which it encounters all things and finds itself, a world which cannot be separated from *Dasein*'s own existential character. Thus, Heidegger gives us an 'existential a priorism' in which human being is always-ahead-of-itself, throwing or projecting the contours of what will then come to characterize itself. (p. 18)

In FD, Heidegger himself slyly hints that he is aware of his modern a priorism. His perplexing use of the ancient concept of *ta mathēmata* for the distinct essence of modern science is a wink to the reader – a reminder that the aprioristic hermeneutics of modernity can reach back as far as you like, and that he himself is a practitioner of this hermeneutics. Heidegger reinforces this at the end of his FD discussion of Newton's first law of motion. He writes there that Democritus's thought presaged the discovery of inertia, and that Galileo was familiar with Democritus. However, continues Heidegger, no one should impugn Galileo for borrowing ideas from Democritus since we cannot understand anything in older philosophers that we don't already know: "As is always the case, that which can already be found in the older philosophers is seen only when one has newly thought it

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out for himself" (FD, p. 62 / MSMM, p. 257). Whatever modernity Heidegger discerns in Galileo has its hermeneutical source in Heidegger himself. While Galileo developed his thought both with the rough and ready planes of Aristotelian *empeiria* and the frictionless planes of modern mathematical physics, for Heidegger, the slope running from Galileo to Newton is as slippery and quick as the movement to what we learn from what we already know.

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## Notes

1 If particular bodies play a secondary role in Newton's physics, it is worth pointing out that bodies in general are, in some sense, his stars. After all, each Newtonian law begins with the phrase "Every body." There is a sense in which bodies have never been more important than they are in Newton. What is lost isn't body, but *this* body in all its particularity. Thank you to an anonymous referee for *Dialogue* for pushing me on this point.

2 See Glazebrook 1998, p. 250.

3 See http://galileo.rice.edu/sci/theories/on_motion.html.

4 See MSMM, p. 268 n.2.

5 The question of whether or not pre-modern science was inductive is outside the scope of this essay. However, it is at least clear that challenges to naïve inductivism by such figures as Hempel and Popper further problematize the distinction between Galilean and Aristotelian science.

6 Standardized units of measurement had not yet been introduced. Galileo likely began his timing by singing marching songs, letting one full note count as a single unit. Later, as his experiments became more sophisticated, he used a device that measured time by collecting and subsequently weighing quantities of water expressed at a regular rate through slender tubes (Drake 1989, pp. 36-39).

7 See Drake 1989, pp. 1-2, 35-49.

8 In 1603, Galileo had himself remarked that "rules deduced by mathematicians simply did not agree with observation" (Drake 1989, p. 37).

9 Drake interprets the latter's attribution of the concept of inertia to Galileo to Newton's reading his own understanding of the concept back into Galileo's writings.

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However, he also notes that "Einstein had christened inertial frames of reference 'Galilean' " (Drake 1999, p. 122).

10 Heidegger doesn't give a reference for his quote. The passage can be found in Galileo on p. 244, at the beginning of the Fourth Day.

11 Compare this with the Scholastic proposition that Heidegger quotes in FD: "*Operare (agere) sequitur esse.* 'The kind of motion follows from the kind of Being' " (FD, p. 66 / MSMM, p. 262).

12 Galileo uses the language of force rather than of violence (*bia*). However, inasmuch as forced motions are always, for Galileo, violations of natural motion, Galilean force is clearly analogous with Aristotelian *bia*.

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