

GALILEO AND THE LAWS OF MOTION

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Philosophy is written in this grand book, the universe, which stands continually open to our gaze. But the book cannot be understood unless one first learns to comprehend the language and read the letters in which it is composed. It is written in the language of mathematics, and its characters are triangles, circles, and other geometric figures without which it is humanly impossible to understand a single word of it; without these, one wanders about in a dark labyrinth. [Galileo, // *Saggiatore*, EN VI 232, Disc.&Op. 237-8]

[Law 1] Each and every thing, in so far as it can, always continues in the same state; and thus what is once in motion always continues to move. [Descartes, *Princ.* II.37]

[Law 2] All motion is in itself rectilinear; and hence any body moving in a circle always tends to move away from the center of the circle which it describes. [*Princ.* II.39]

[Law 3] If a body collides with another body that is stronger than itself, it loses none of its motion; but if it collides with a weaker body, it loses a quantity of motion equal to that which it imparts to the other body. [*Princ.* II.40]

In the beginning [God] created matter, along with its motion and rest; and now, merely by his regular concurrence, he preserves the same amount of motion and rest in the material universe as he put there in the beginning. ... For we understand that God's perfection involves not only his being immutable in himself, but also his operating in a manner that is always utterly constant and immutable. Now there are some changes whose occurrence is guaranteed either by our own plain experience or by divine revelation, and either our perception or our faith shows us that these take place without any change in the creator; but apart from these we should not suppose that any other changes occur in God's works, in case this suggests some inconstancy in God. **Thus, God imparted various motions to the parts of matter when he first created them, and he now preserves all this matter in the same way, and by the same process by which he originally created it; and it follows from what we have said that this fact alone makes it most reasonable to think that God likewise always preserves the same quantity of motion in matter. [*Princ.* II.36]**

The reason for this second rule is the same as the reason for the first rule, namely the immutability and simplicity of the operation by which God preserves motion in matter. For he always preserves the motion in the precise form in which it is occurring at the very moment when he preserves it, without taking any account of the motion which was occurring a little while earlier. [*Princ.* II.39]

Since God preserves the world by the selfsame action and in accordance with the selfsame laws as when he created it, the motion which he preserves is not something permanently fixed in given pieces of matter, but something which is mutually transferred when collisions occur. [*Princ.* II.42]

Nature ... is inexorable and immutable; she never transgresses the laws [*leggi*] imposed upon her, or cares a whit whether her abstruse reasons and methods of operation or understandable to men. [Galileo, *Letter to the Grand Duchess*, EN V 316, *Disc & Op.* 182]

We bring forward a brand new science concerning a very old subject. There is perhaps nothing in nature older than MOTION, about which volumes neither few nor small have been written by philosophers; yet I find many essentials of it that are worth knowing which have not even been remarked, let alone demonstrated. [*Discorsi*, EN VIII 190]

Proposition II. Theorem II

If a moveable descends from rest in uniformly accelerated motion, the spaces run through in any times whatever are to each other as the duplicate ratio of their times; that is, are as the squares of those times. [*Discorsi*, EN VIII 209]

I say that motion is equably or uniformly accelerated which, abandoning rest, adds on to itself equal momenta of swiftness in equal times. [*Discorsi*, EN 198, 205]

And first, it is appropriate to seek out and clarify the definition that best agrees with that which nature employs. Not that there is anything wrong with inventing at pleasure some kind of motion and theorizing about its consequent properties ... But since nature does employ a certain kind of acceleration for descending heavy things, we decided to look into their properties so that we might be sure that the definition of accelerated motion which we are about to adduce agrees with the essence of naturally accelerated motion. [*Discorsi*, EN VIII 197]

It may also be noted that whatever degree of speed is found in the moveable, this is by its nature indelibly impressed on it when external causes of acceleration or retardation are removed, which occurs only on the horizontal plane: for on declining planes there is cause of more acceleration, and on rising planes, of retardation. From this it likewise follows that motion in the horizontal is also eternal, since if it is indeed equable it is not weakened or remitted, much less removed. [*Discorsi*, EN VIII 243]

When a projectile is carried in motion compounded from equable horizontal and from naturally accelerated downward [motion], it describes a semiparabolic line in its movement. [*Discorsi*, EN VIII 269]

Every body constituted in a state of rest but naturally capable of motion will move when set at liberty only if it has a natural tendency toward some particular place; for if it were indifferent to all places it would remain at rest, having no more cause to move one way than another. Having such a tendency, it naturally follows that in its motion it will be continually accelerating. [*Two World Systems*, EN VII 56, Drake 31-32]

...the parts of the earth do not move so as to go toward the center of the universe, but so as to unite with the whole earth (and that consequently they have a natural tendency toward the center of the terrestrial globe, by which tendency they cooperate to form and preserve it)... [*Two World Systems*, EN VII 57-8, Drake 33]

Let us suppose that among the decrees of the divine Architect was the thought of creating in the universe those globes which we behold continually revolving, and of establishing a center of their rotations in which the sun was located immovably. Next, suppose all the said globes to have been created in the same place, and there assigned tendencies of motion, descending toward the center until they had acquired those degrees of velocity which originally seemed good to the Divine mind. These velocities being acquired, we lastly suppose that the globes were set in rotation, each retaining in its orbit its predetermined velocity.... *Two World Systems*, EN VII 53, Drake, 29

Generally speaking, I find that he philosophizes much more ably than is usual, in that, so far as he can, he abandons the errors of the Schools and tries to use mathematical methods in the investigation of physical questions. On that score, I am completely at one with him, for I hold that there is no other way to discover the truth. But he continually digresses, and he does not take time to explain matters fully. This, in my view, is a mistake: it shows that he has not investigated matters in an orderly way, and has merely sought explanations for some particular effects, without going into the primary causes in nature; hence his building lacks a foundation. [Descartes to Mersenne, 11 Oct. 1638, AT II 380]

[I plan] three books on local motion—
an entirely new science in which no
one else, ancient or modern, has
discovered any of the most
remarkable characteristics [*sintomi*]
which I demonstrate to exist in both
natural and violent movement....

[Galileo to Vinta, 7 May 1610, EN X
351-2]

I'm interested in examining what might be the characteristics [*sintomi*] which accompany the motion of a moving body, which, starting from a state of rest, it goes on moving with a speed that constantly increases in the same way...
[Galileo to Baliani, 7 January 1639, EN XVIII 12]