What Newton Really Meant

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Newton's First Law is a lie! That is to say, the principle that everybody calls "Newton's First Law", the one they tell you about in school, the one physicists and scholars have for centuries attributed to Newton — that principle is not *Newton's* First Law. It is a clumsy mistranslation of the Latin principle that Isaac Newton labelled the First Law of Motion, an eighteenth century mistake that somehow managed to fly under the radar. Newton's actual First Law is a much more powerful, far more interesting principle than people have taken it to be.

But before I go into that, let me back up a little to remind you of what Newton's First Law is supposed to say, and to tell you about the time I first knew *something* was up.

As long as a moving object is left alone (and is not yanked or pushed or tugged by any external force), it will keep on going at constant speed in a straight line forever — that's Newton's First Law as it's normally understood. To me, like most people, this principle did not ring true right away when I was taught it in school. After all, if you kick a ball or a shopping cart, then leave it alone, it won't keep moving in a straight line forever!

But as my teacher explained, the reason a rolling shopping cart slows down is that it isn't actually free of external forces. The ground the cart rubs up against and the air that it bumps into are both pushing it back… Then what about the moon, say? The moon moves through empty space, and still it goes in circles rather than in a straight line! Well, the moon is not really force-free either: the tug of the earth's gravity stops it from flying off into the void in a straight line. And so on: in practice, nothing is ever in perfectly stable uniform linear motion, the way Newton's Law describes. But then there is always some force or other to explain why that object is supposedly exempt from the Law. But at this point, you might wonder, as I did: are there *any* bodies whose motions are governed by the First Law of Motion?

Will this bicycle crash or keep moving uniformly in a straight line forever?

You'd be right to wonder about that! By Newton's own lights, every body in the universe is subject to forces, in particular gravity. So strictly speaking, force-free bodies do not exist at all. But if that is so, then Newton's celebrated First Law of Motion starts to seem like a bit of a dud. What good is a law of nature that governs nothing? Why make *that* your First Law?

"Well," said my teacher, "the law tells us that if there *were* force-free bodies then they *would* move in straight lines." I thought it was a lame excuse.

Much later, in college, I took a class about the philosophy of physics, and found out that I was not the only one who had been bothered by this. Famous physicists like Henri Poincaré and Arthur Eddington had written about the issue, and philosophers had come up with all sorts of excuses on Newton's behalf. Some of those excuses were even lamer than my teacher's, some were pretty cool. Other people thought Newton had simply messed up, and Eddington even poked a little fun at him, offering a zingy paraphrase of the First Law: "Every body continues in its state of rest or uniform motion in a straight line, except insofar as it doesn't."

Still, I found it hard to believe this was just an oversight on Newton's part. I had read some of Newton's writings by that time, and I knew he was a strikingly clear thinker who chose his words with extreme care. So I went to the library and looked up the newest translation of Newton's *Principia*, so I could read the First Law in his own words. Here it is:

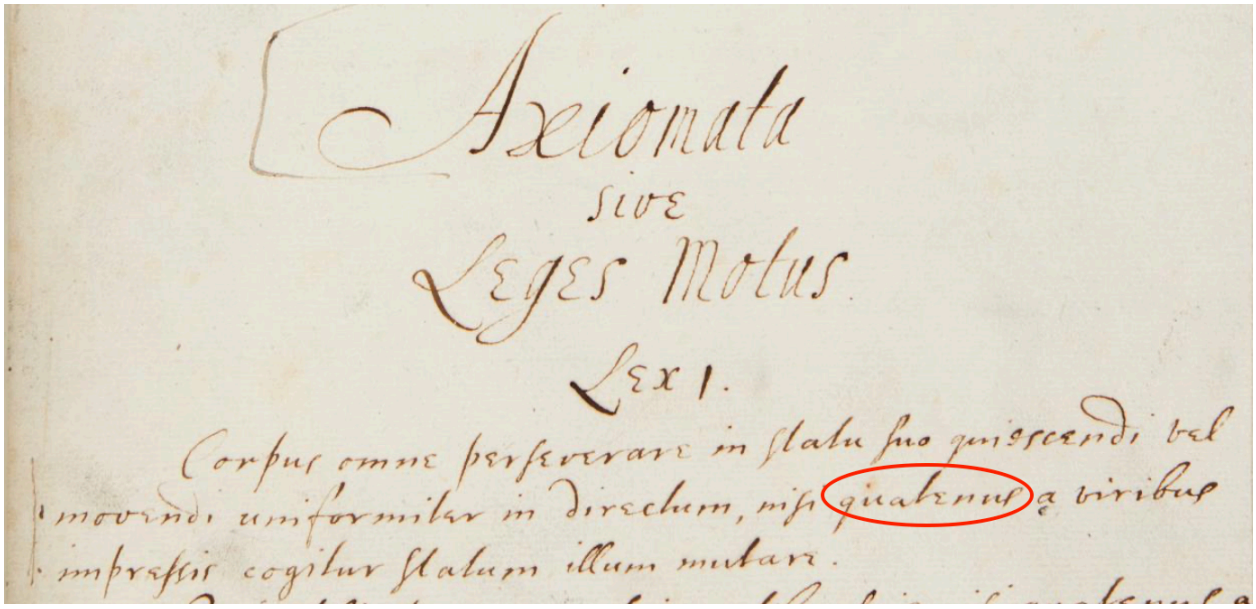
> Every body perseveres in its state of being at rest or of moving uniformly straight forward, except insofar as it is compelled to change its state by the forces impressed.

Carefully read the statement again, and just ask yourself this: what does this principle say about bodies that are subject to forces?

Going by everything I had ever been taught, and everything I had ever read about the First Law, the answer should have been "nothing". All these physicists and philosophers and scholars I mentioned who wrote about the meaning of the First Law, they all took it for granted that the First Law is just about the motion of force-free bodies.

But it is crystal clear that the above statement, the principle labelled "Law I" in Isaac Newton's *Principia*, does concern the motion of bodies subject to impressed forces. What it says about those bodies is that they diverge from their state of rest or uniform rectilinear motion *only insofar as the impressed forces compel them to*. Read it again if you don't believe me.

As if to underline this point, Newton follows up his formulation of the law with a very telling illustration: "A spinning top, whose parts by their cohesion continually draw one another back from rectilinear motions does not cease to rotate, except insofar as it is retarded by the air." The parts of a spinning top are not force-free at all, and obviously don't move in straight lines. But as Newton explains, their state of motion changes *only to the extent* that the forces impressed compel them to. So this is a perfectly good illustration of what the First Law actually says. By



The First Law of Motion in Newton's own handwriting, with the word "quatenus" ("insofar") circled

giving this example, Newton explicitly shows us how the First Law, as he understands it, applies to accelerating bodies which are subject to forces — that is .

How did so many experts and smart people miss this? That question bugged me too, until I did some digging a few years ago. It turns out that for most of its history, almost every available translation of Newton's Latin *Principia* was based on the original 1729 English translation by Andrew Motte. Motte's edition was published two years after Isaac Newton's death, and he almost certainly prepared it without Newton's knowledge or permission. While it is mostly a very good translation, Motte skipped one persnickety little word in the First Law: the word *quatenus*, meaning "insofar". As a result, here is the translation of the First Law that he (and the rest of us) ended up with: "Every body perseveres in its state of rest, or of uniform motion in a right line, *unless* it is compelled to change that state by forces impress'd thereon."

Substituting "unless" for "except insofar" makes all the difference. Motte makes it sound as though the law makes an *exception* for bodies subject to forces, instead of adding a *qualification*. When the *Principia* was finally retranslated in 1999, the new translators Cohen and Whitman fixed Motte's mistake (it was their translation I had found in the library). But by that time, Motte's misreading of the First Law had become so deeply entrenched that even Cohen and Whitman do not appear to have noticed what a transformative difference this wording makes.

I am not saying physics would have gone differently if Newton's *insofar* had not been lost in translation. As I explain in my paper on this topic, Euler's reformulation of Newton's Second Law ended up making the First Law somewhat redundant. For that reason, the fact that people had the wrong idea about Newton's First Law did not much hamper our understanding of Newtonian Mechanics as a whole.

Still, setting the record straight about Newton's First Law does transform our view of the import and role of the Law itself. With the *insofar* back in place, it becomes clear that Newton's First Law of Motion is about change as much as it is about constancy. It is a principle about the extent to which bodies *diverge* from their state of motion (namely as much as the impressed forces compel them to do). We can rephrase the point this way: whenever a body's speed or direction changes, that change is always due to a force.

Or in a nutshell, *all changes in motion are forced*.

So no, the First Law of Motion is not about imaginary situations, as my physics teacher thought it was. It concerns real-world changes of motion. We live in a dynamic, brimming, whizz-popping universe, filled with swarming atoms and swirling molecules, speeding comets and swivelling galaxies. And each turn and twist in all that vast confusion, every change in speed and every tilt in direction, is governed by Newton's First Law.