PhyzGuide: Newton's First Law
inertia

Every body persists in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by unbalanced forces impressed on it.

Isaac Newton
Philosophaei Naturalis Principia Mathematica

The principle we describe as Newton's first law was actually first discovered by Galileo. (Many of Newton's "discoveries" originated with people other than Sir Isaac.) Before Galileo, the explanation for natural motion was the one put forth by Aristotle. Aristotle theorized that things move to first their natural place in the universe and come to rest when they get there.

Galileo, on the other hand, proposed that objects maintain their state of motion: If they are at rest, they remain at rest unless acted on by an external force. Easy enough. But Galileo went on to say that objects moving in a straight line with constant speed (constant *velocity*, in other words) remain moving in a straight line with constant speed, unless acted upon by an external force.

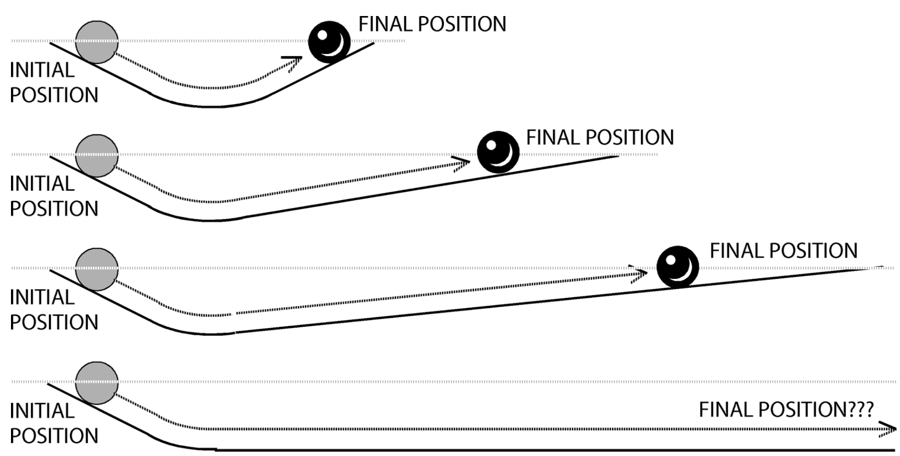
"That's **so** dumb," charged Galileo's many antagonists (Galileo had a knack for making enemies), "you're saying that if I set a brick into motion on a tabletop, it will maintain constant velocity? Get outta town!"

"Of course not, propeller-heads!" Galileo explained. "In the case of the brick, a *frictional* force acts on the brick to bring it to rest. But consider an experiment I've done:"

"Allow a marble to roll down an incline and back up another. The marble rolls to a height equal to that at which it was released.

It rolls back up to its original height regardless of how far it has to go lengthwise.

So what would happen if there were no incline for the marble to roll up? It couldn't attain its original height, and would theoretically continue on in a straight line with constant speed forever...."



Of course, the marble does not continue forever. Air resistance and rolling friction forces slow the marble to a stop. But if a marble were given a push in deep space, it would travel an exceedingly long distance before being acted on by external forces. To understand a concept like this we need to "undress nature." We must look past superficial complexity to see the simple characteristics of nature. Once the fundamental properties are understood, we can take into account other, more complex factors.

The simple characteristic of nature that *Newton I* points out is that objects are "lazy." If they are at rest, they have no "desire" to get up and move. If they are to move, something else will have to kick them in the rear (providing the unbalanced external force). If they are moving at a constant velocity, they will continue at constant velocity. If a force pushes them along, they will go faster. If a force pushes against them, they will slow down. The "laziness" of matter is called **inertia.** Formally, inertia is defined as the apparent resistance a body offers to changes in its state of motion.

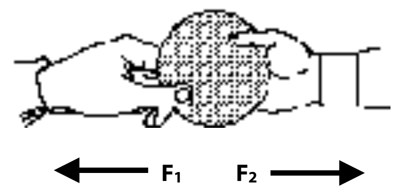
"LEGGO MY EGGO!" AND OTHER PRINCIPLES OF SCIENCE

Let's disregard the acceleration of falling bodies for a moment and focus our attention on an object moving horizontally. (This way we don't have to worry about the effects of gravitational force.)

Now, we have seen that all objects have inertia (mass), or "resistance to change in motion." To move, an object must be acted on by an unbalanced, external force. Not just a force. An *unbalanced, external* force.

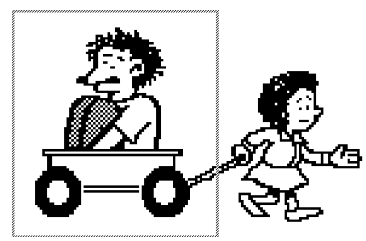
What is meant by an **unbalanced** force, and why is it so important that a force be unbalanced in order to change the motion of a body?

This is the famous "Leggo my Eggo!" principle: If an object is pulled by equal forces in opposite directions (that is, if the forces acting on the object are **balanced**), it won't go anywhere. It will just sit there. (Of course, if the opposing forces are great enough, the object could be ripped apart.) If one of the forces were removed—so that the forces were no longer balanced—the object *would* accelerate.



The **net** force is zero: $\sum \mathbf{F} = 0$

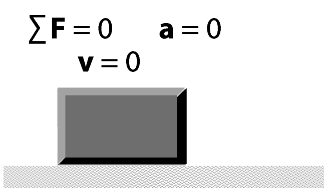
What about this business of forces having to be "**external**"? Think about sitting in a wagon. You wish to make the wagon (and yourself) accelerate. If you pushed or pulled on the wagon, you'd accomplish nothing.* The *system* (the particular collection of objects of interest) that you wish to accelerate consists of the wagon and yourself. If *you* push on the wagon, one part of the system is simply pushing on another; this is an **internal** force, and no acceleration would result. If someone were to come along and pull you, *his or her* pull would be an **external** force, and you would accelerate.



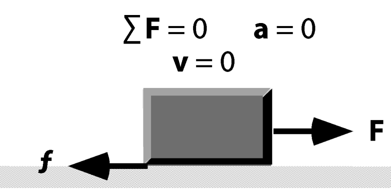
SYSTEM

External Force $\sum F > 0$

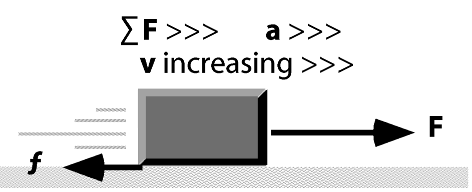
Consider the following (remember: we're considering only *horizontal* forces).



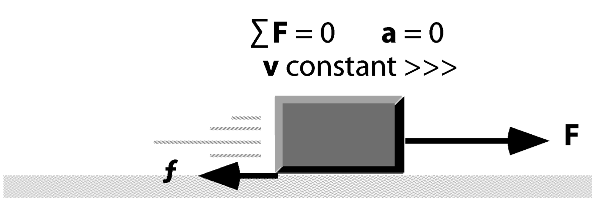
1. A brick at rest remains at rest.



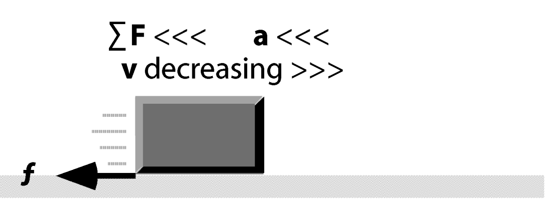
2. If you were to push lightly on the brick, (F) it would not move, because friction force (f) between the brick and the surface would **balance** your exerted force.



3. You can produce an **unbalanced** force by pushing harder. The friction force is still there, but your exerted force is bigger. The unbalanced force produces an acceleration.



4. If you wish to keep the brick moving at a constant speed, you must exert a force to **balance** the friction force. If the forces are balanced, there is no acceleration, and velocity remains constant.



5. If you stop exerting a force, the friction force persists and is now **unbalanced** so a deceleration is produced until the brick comes to rest.

*With some practice and good instincts, you can learn to manipulate the friction in the bearings of the wheels to cause jerky forward (or backward) net motion. That would not be possible if the bearings were frictionless.