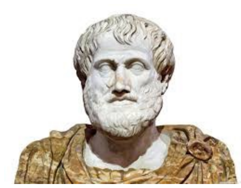
MOTION

How to Best Understand Motion

The history of thinking and logic (philosophy) is closely associated with science. After all, science is all about logic.



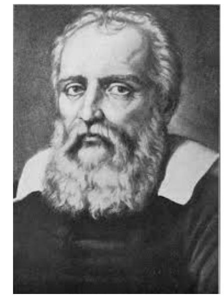
Aristotle

The Greek philosopher Aristotle (384 - 322 BCE) contemplated the nature of motion, and reasoned that the motion of a body was caused by pushing or pulling on that body. On the surface, that explanation makes sense. If you push a rock, it will move until you stop pushing at which point it will stop. If you pull a wagon, it will move until you stop pulling at which point, it will stop.

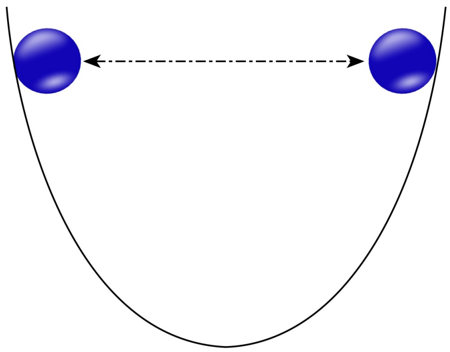
However, there was a flaw with Aristotle's logic. If an arrow is pushed by the string of the bow, why did the arrow keep moving after contact with the string was lost. If a spear was thrown by a warrior, why did the spear continue to move after the spear left the warrior's arm? Unfortunately, Aristotle's logic was so simple and intuitive, that it took almost 2000 years before a better understanding of motion could be develop.

The next major step in understanding momentum could be attributed to Galileo Galilei (1564 - 1642). Galileo was an Italian physicist, mathematician, engineer, astronomer and philosopher who played a major role in the scientific revolution during the Renaissance.

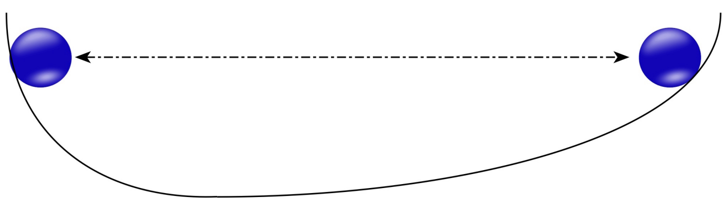
Galileo conducted a thought experiment in which he considered the following. Suppose a ball is released in a bowl and allowed to roll down. As it does so, it will travel to the opposite side of the bowl to approximately the same height before it momentarily stopped and reversed direction. Note: If it were not due to friction, the ball would return to the same height.



Galileo Galilei



Now, Galileo reasoned, What if the bowl was not symmetrical? In the scenario pictured below, the ball would travel a greater distance but would come to a momentary stop at approximately the same height before it reversed course.



In this case, the ball travelled a greater distance before coming to a stop. This was interesting, but Galileo went one step further. What if the ball rolled to a flat surface? Surely the ball would roll an infinite distance before coming to a stop.

As a result of this thought experiment, Galileo reasoned that motion is a natural state of nature. He qualitatively developed the law of inertia. An object at rest tends to remain at rest while a body in motion tends to remain in motion.

An object in motion tends to remain in motion. Motion is a natural state of nature.

GALILEO GALILEI

The next leap in the understanding of motion was identified by Isaac Newton (1643 - 1727). Newton reasoned that the real question was not “Why to things move” but rather, “What causes motion to change”. He expanded on Galileo’s reasoning and determined that changes in motion were to be understood, not uniform motion because uniform motion is a natural state of nature.

Isaac Newton

Newton quantified motion by developing the concept of momentum. He defined momentum as the product of mass and velocity. (Note: velocity is a vector quantity and involved a directional component). In order to measure the change in motion, he considered the manner in which momentum changed over time. He observed that if the mass of the object was not altered when its motion changed, then the change in motion is due to the mass of the object times its change in velocity. It is worth noting at this point that a change in velocity is defined as acceleration (also a vector quantity). Therefore, the change in motion is caused as a result of mass times acceleration. He subsequently defined this unit as Force.

Mathematically, this is expressed as:

$$\vec{F} = m\vec{a}$$

I have included the arrows over the symbols of force (F) and acceleration (a) to clearly denote that they are vector quantities and have a directional component.

This mathematical formula makes sense in that it predicts real world behaviour. It predicts that acceleration of a body is directly proportional to the force applied to that object. The more force is applied to an object, the greater is its acceleration. Also, acceleration is inversely proportional to the mass of the object. Given a certain force, a heavier object will have a lower acceleration than an lighter object.

At this point, it is important to realize that motion depends on an unbalanced force. We can have the force of gravity acting on our bodies, but the earth is matching that force pushing our bodies upward. Since the force is balanced in both directions, there is no movement. We do not travel downward into the earth nor upward into the sky.

As a result of this logic, Newton developed his three laws of motion.

Law #1:

An object at rest tends to remain at rest and an object in motion tends to remain in motion unless acted on by an unbalanced external force.

Isaac newton

Law #2:

The acceleration of a body is directly proportional to the net force and inversely proportional to the mass of the body.

Isaac newton

Law#3:

For every force acting on one body, there is an equal and opposite force acting on the first body from the second body.

Isaac newton

These three laws form the basis of Newtonian Physics. They were used to design the structures and machines commonly visible in the modern age.

However, our understanding of motion does not end with Newtonian Physics. Newtonian motion fails to explain observations involving bodies travelling at very high speeds (those approaching the speed of light). Relativistic motion was developed by Einstein to deal with such scenarios. Likewise, quantum physics was developed to deal with the motion involving very small bodies, such as atoms.