Physics

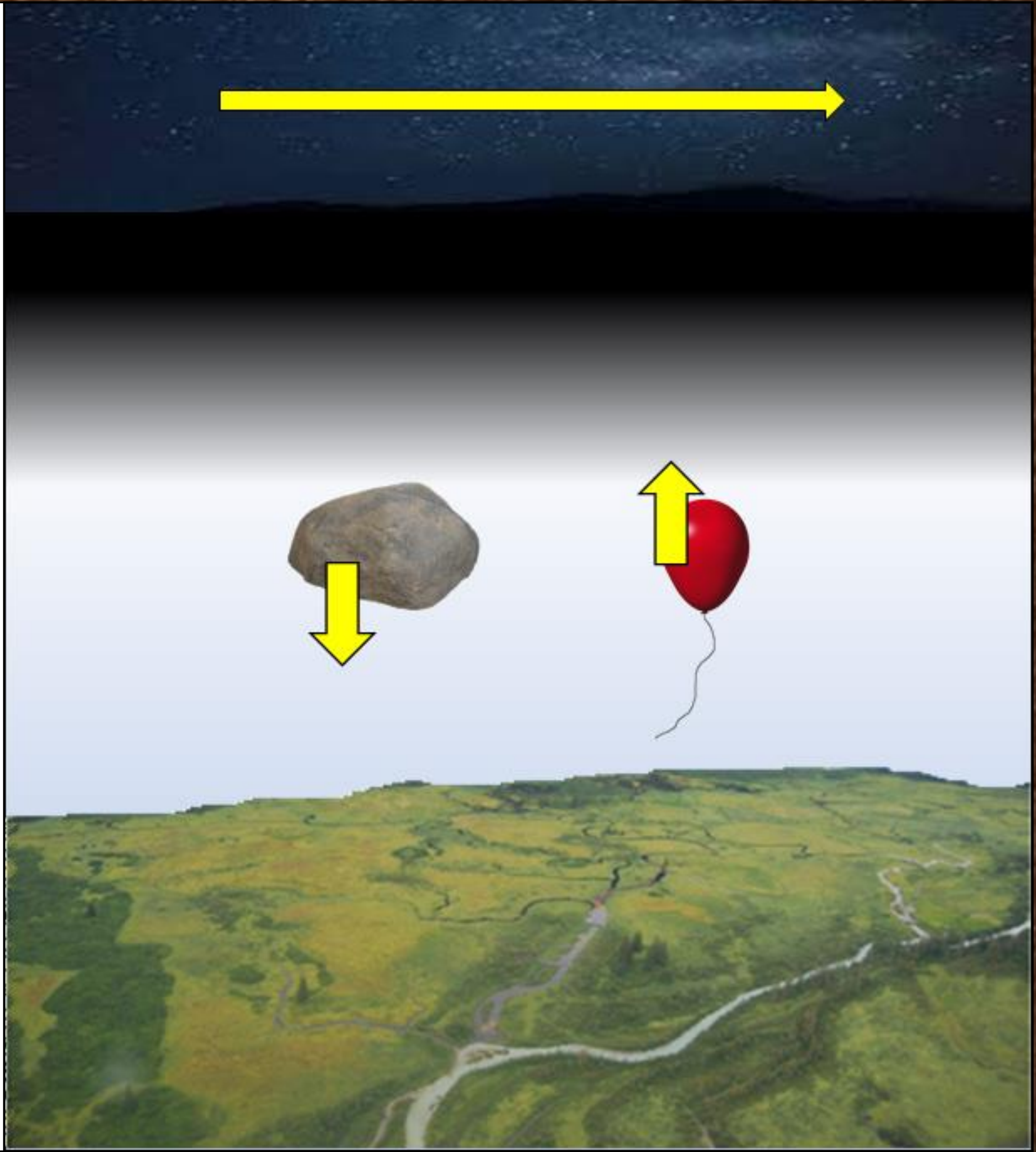
Chapter 1a

Laws of Motion

People have thought about how things move for a long time. Not all theories were right or well thought out.

Aristotle had the most influence on thoughts about motion. His theories held for a very long time until people began to critically examine them. Critical examination is essential for a good scientist and we will say more about that in a minute. Because no one thought critically about Aristotle's ideas for so long, people were blind to the real nature of motion. Some of the key points of Aristotle's theory are:

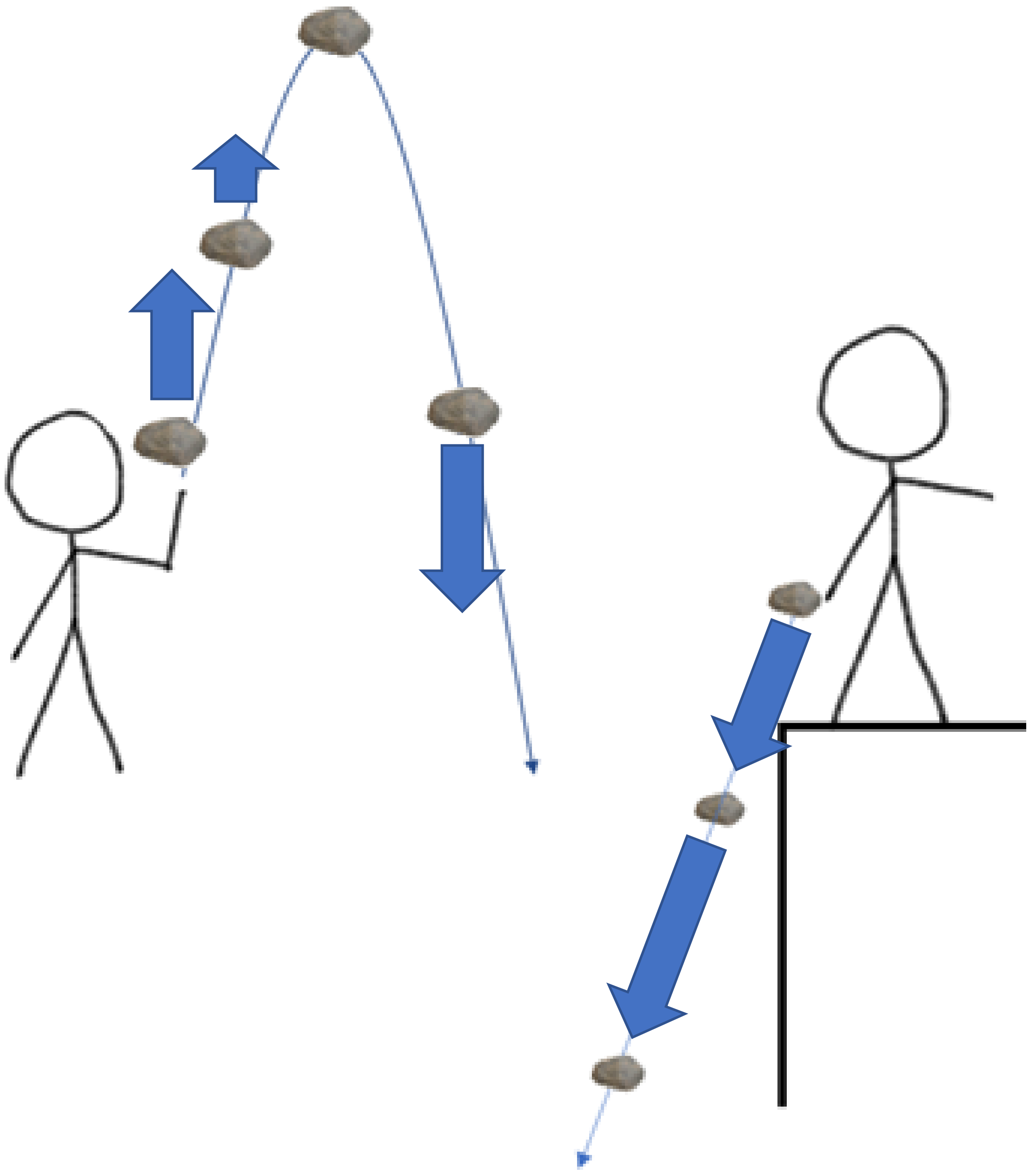
- All things have a natural place and natural motion moves them to that place:
  - The sun, planet, stars, etc. move around the earth in fixed spheres.
  - Air bubbles in water want to move up.
  - Leaves want to fall to the middle of the earth.
- Living beings can cause violent motion that displaces objects.
- All motion is caused by the combination of the two kinds of motion.
- Objects have speed because of violent motion.
- Objects stop moving when there is no more violent motion.
- Objects with less mass move slower.



The problem is that many things do not behave in the way Aristotle predicted. For example, if you throw a stone straight up it gradually slows down. This makes sense if it has violent motion. Once it leaves the living being who threw it, the violent motion decreases. Then the stone starts its natural movement downward to the earth. Again, this makes sense. But what if you throw the rock down?

According to Aristotle's theory if you throw the rock down you are giving it a bit of violent motion, but as it moves away from you the violent motion should diminish. It always has the same natural motion. Theoretically, the rock should slow down as it falls until it reaches its natural motion. Instead, we see the rock moving faster as it falls. This behavior goes against the theory. Something must be wrong.

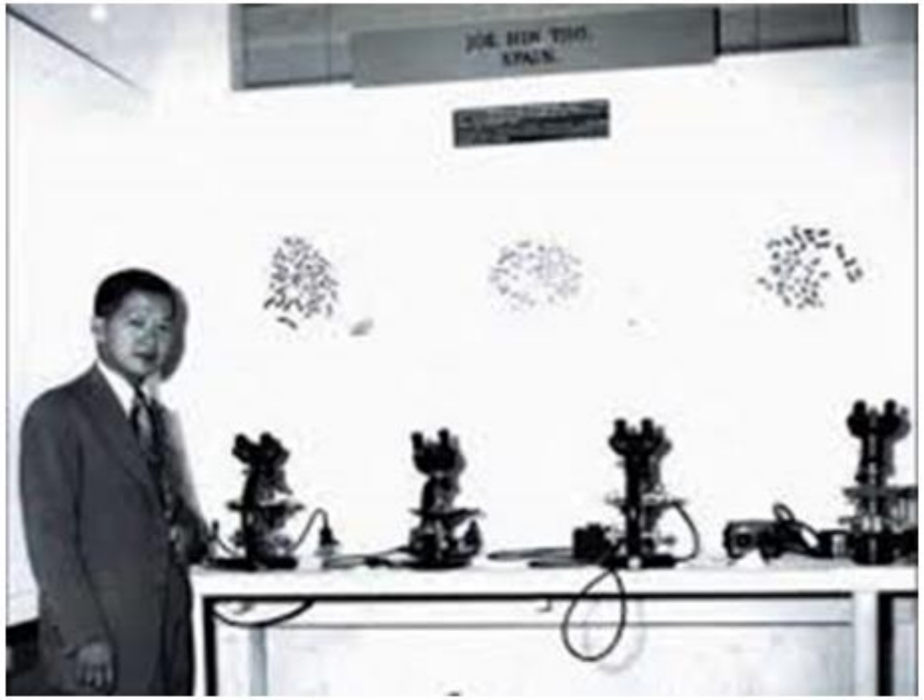
This is nothing new. This is the way science works. We observe some phenomenon. We form a theory of how it works. Over time other observations can point out problems with the theory. Many people just ignore these problems. A good scientists uses the observations that don't fit to figure out a better theory.

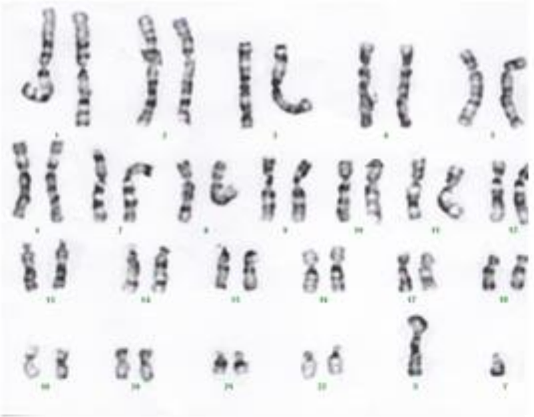


There is a story that explains this attitude about observations that don’t fit. In 1923 a scientist name Theophilus Painter published a paper where he said that humans have 24 pairs of chromosomes. There were others who had identified 19, 20, 21, 22, even 23 pairs of chromosomes, but Painter said that he had counted very carefully and if others hadn’t counted well enough, they might be missing some. At the time, counting chromosomes was very hard, so if people couldn’t find the 24th pair, it was understandable.

33 years later, a pair of scientists in Sweden, Albert Levan and Joe-Hin Tjio, published a beautiful photograph proving that there were only 23 pairs. There had been many advances since that time so they could be sure that their count was accurate, but they still sat on the data for a long time. They were convinced that 24 was wrong, but they didn’t want to say anything until they have enough proof. Worse, their collogues already suspected 23 was the right number, but they didn’t want to say anything at all. Worst of all, Tjio wasn’t even a geneticist—he was a botanist.

These were not the only scientists to think something was wrong with 24. They were just the first who were willing to think critically and maybe… maybe look foolish in front of everyone else. Have you ever heard of the Emperor’s New Clothes? Sometimes it takes a little child to say the truth no one else wants to say. Or maybe a botanist.



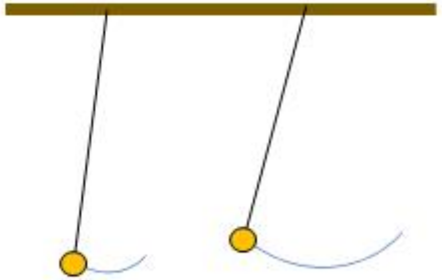


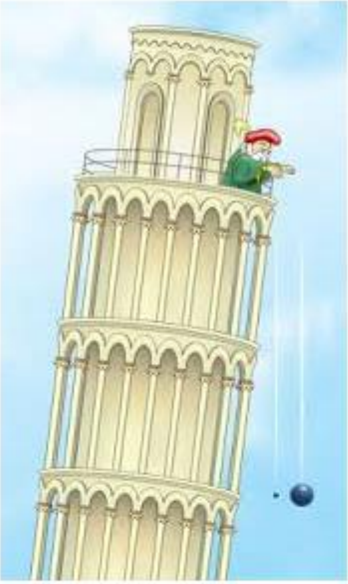
One man with this kind of courage was Galileo Galilei. He started studying to be a doctor, but one day noticed that a chandelier swinging back and forth always took the same time to swing—regardless of how long the swing was. This made no sense, but he had seen it with his own eyes, so he went home and designed an experiment. He created two pendulums that were exactly the same in every way. He gave one a small swing; the other a large swing. He watched them and they kept the same time regardless of how far they had to swing.

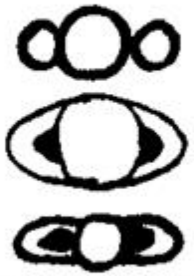
Even without understanding why, he had already shown behaviors of motion that didn't match Aristotle's predictions (they should have had the same speed and different swing times). He began studying math and science to see what else might be wrong.

Eventually he did some very famous experiments proving many things about Aristotle's work were wrong. He dropped two balls of different masses from the tower of Piza. Aristotle predicted they would drop at different speeds, but Galileo found that they dropped at the same speed. His biggest contributions, however, were to astronomy where he used telescopes to look into space and he saw that the objects moving around the earth…weren't moving around the earth. He saw that there were moons of Jupiter moving around that planet instead. He saw rings on Saturn.

It was this proof that the earth wasn't special, that the rest of the universe didn't move around us that got him in trouble with the Pope. I guess some people aren't science fans.







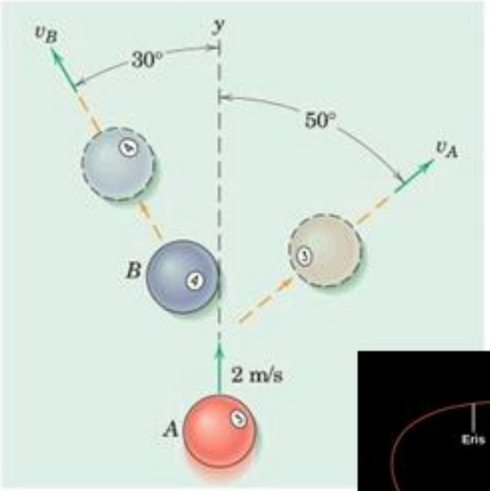
These are sketches of three drawings Galileo made of Saturn through his primitive telescope. ("New Worlds," Couper & Henbest, p.86.)

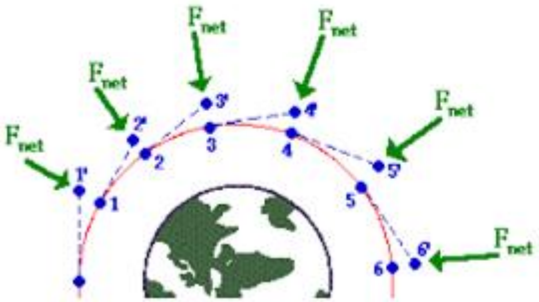
Another critical thinker was Isaac Newton. He was a observing a lot of things moving in a way that didn't make sense according to Aristotle. The most famous example was the apple he saw fall from the tree. According to Aristotle, the only thing that could cause violent motion was a living being, but the apple was moving toward the earth not because anything had pushed it, only because it had been released to move.

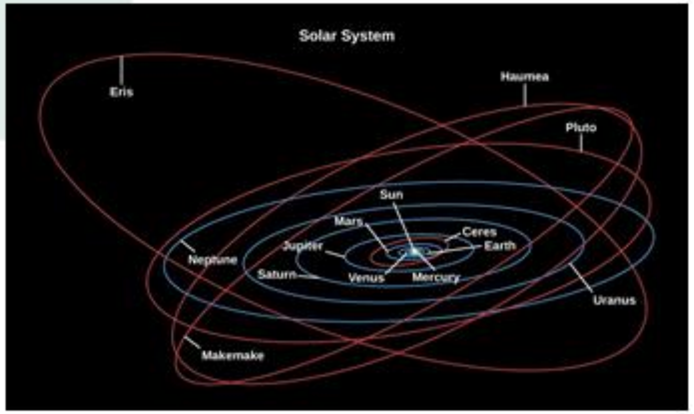
Newton began to think about things in a different way from Aristotle. In his theory, Newton said that there are forces that push things, that give them motion. He also said that all things will keep moving until the are stopped by another force. These forces can push and pull in opposite directions and sometimes an opposite force (like the air pushing back on a ball) will slow things down.

In Aristotle's theory, objects moved because of their properties. In Newton's theory, objects moved because of forces. Objects could create forces. Forces could stop motion. Forces could be added. Forces on objects explained everything and eventually explained the way planets and moons moved around the sky.

Newton's laws of motion are the one we use today.



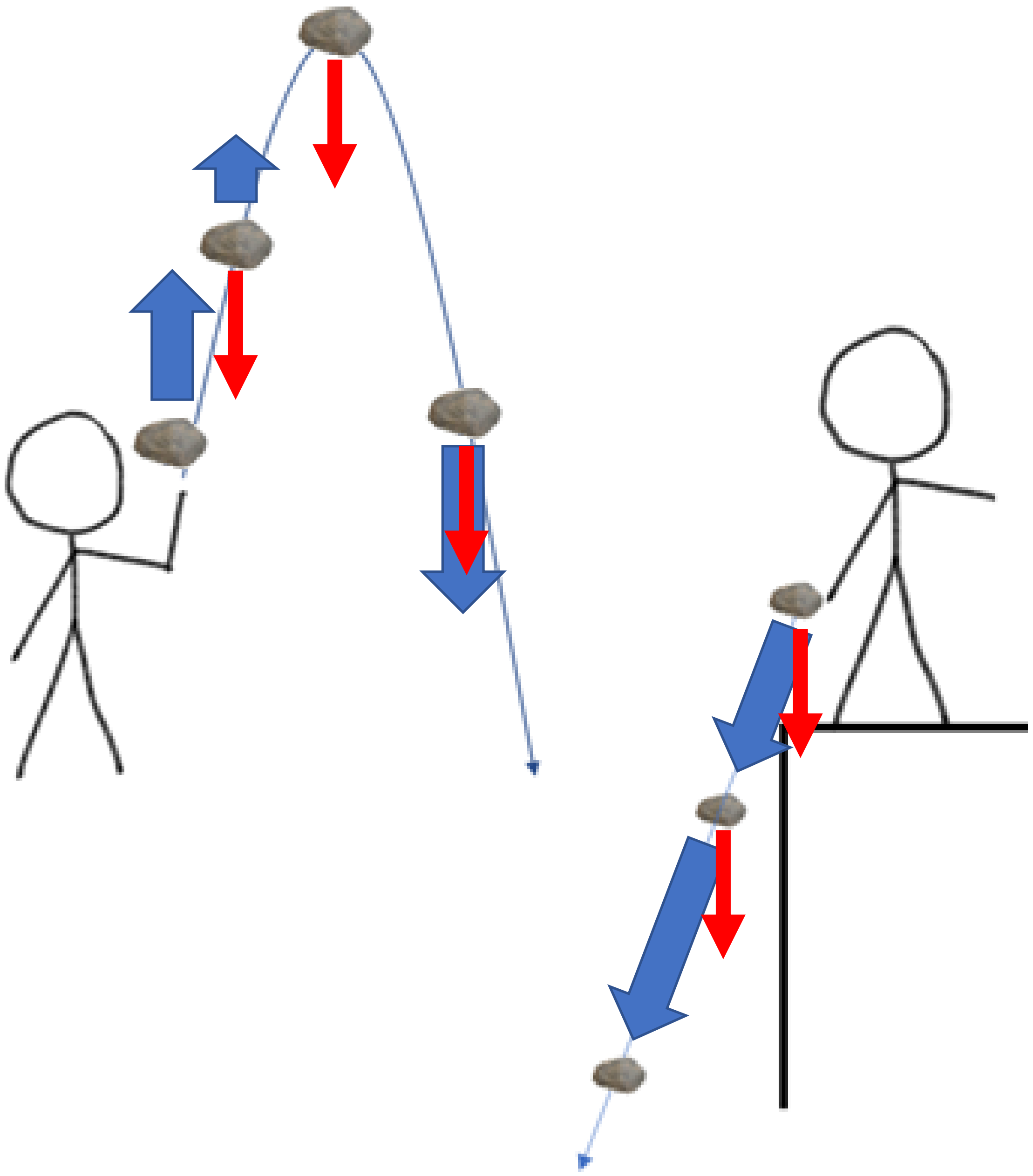




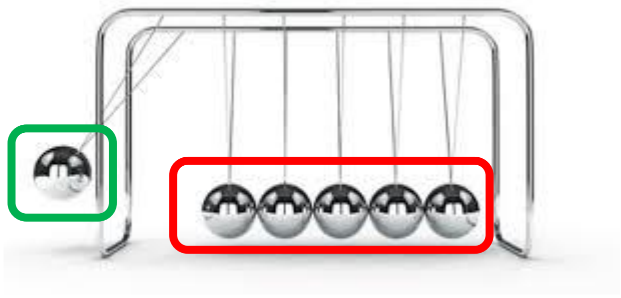
Let's see how well Newton can explain our rock. When you throw the rock, you use a force to accelerate the rock and give it a velocity (i.e. a speed). Once it leaves your hand, the rock is pulled down by gravity which is opposite to the direction you threw it. As a result, the force of gravity is subtracting velocity from the rock. Once velocity reaches zero, gravity keeps pulling the rock down, getting faster as it travels. This is exactly what happens, and it makes sense.

How about the rock thrown down. When you throw the rock, you use a force to accelerate the rock and give it a velocity. Once it leaves your hand, the rock is pulled down by gravity which pulls with the direction you threw it. As a result, the force of gravity is adding velocity to the rock. Again, this is exactly what happens, and it makes sense.

Newton's laws of motion give us the tools to understand what is happening in all sorts of circumstances where Aristotle's theory of motion does not. If a tree falls, what living thing moved it? If a person jumps, why does the person eventually fall down? If two people ran into each other, which one is giving violent motion to the other? If a man spits into the wind, why does it blow back on him? All of these make sense in terms of masses, acceleration, velocity, and forces, but Aristotle can't answer them.

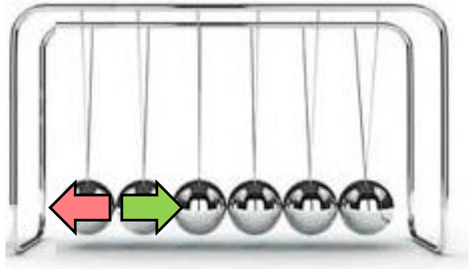


Newton's laws are easily demonstrated by a device known as a Newton's Cradle. At first, the five balls in red are at rest. None of them will move unless something gives them a push. The one green ball is moving. It will not stop until something gives it a push.



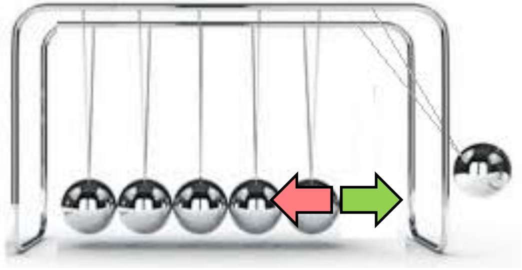
An object in motion tends to stay in motion unless acted upon by another force or object. An object at rest tends to stay at rest unless acted upon by another force or object.

When the moving ball hits the others, it creates a force that pushes the next ball. At the same time, in reaction to that force, the second ball pushes back on the moving ball. This second force stops the first ball at the same time that the second ball starts to move. This action and reaction moves through all the balls until the very end.



For every action there is an opposite and equal reaction.

When the reaction reaches the end, the last ball is accelerated by the force it receives. The size of the acceleration depends on the size of the force and the size of the mass.



F=ma

As you learn more about the laws of motion these elements of Newton's laws will occur time and time again. You will use them mathematically and with their units. The units will help you to ensure the mathematics are consistent. The math will help you to work out valuable information you don't have.

Consistency in science is important. People have worked long and hard to work out mathematical representations of physical laws. Once that is done, they assign units that describe the physical values. Each equation is a beautifully balanced model of the real world.

One other important note. Newton didn't just develop the laws of motion. He also created a whole new kind of math to understand that motion. Calculus is meant to be used with physics and the equations we will use here are the algebraic results of the calculus. That's okay, but you should now that to fully understand where these equations come from you need the calculus that goes with them.

$$F = ma$$

$$\mathrm{N} \qquad \mathrm{kg} * \frac{\mathrm{m}}{\mathrm{s}^2}$$

$$V_x + V_y = V$$

$$\frac{\mathrm{m}}{\mathrm{s}} \qquad \frac{\mathrm{m}}{\mathrm{s}} \qquad \frac{\mathrm{m}}{\mathrm{s}}$$