... the use of our intelligence quite properly gives us pleasure. In this respect the brain is like a muscle. When we think well, we feel good. Understanding is a kind of ecstasy.

Carl Sagan

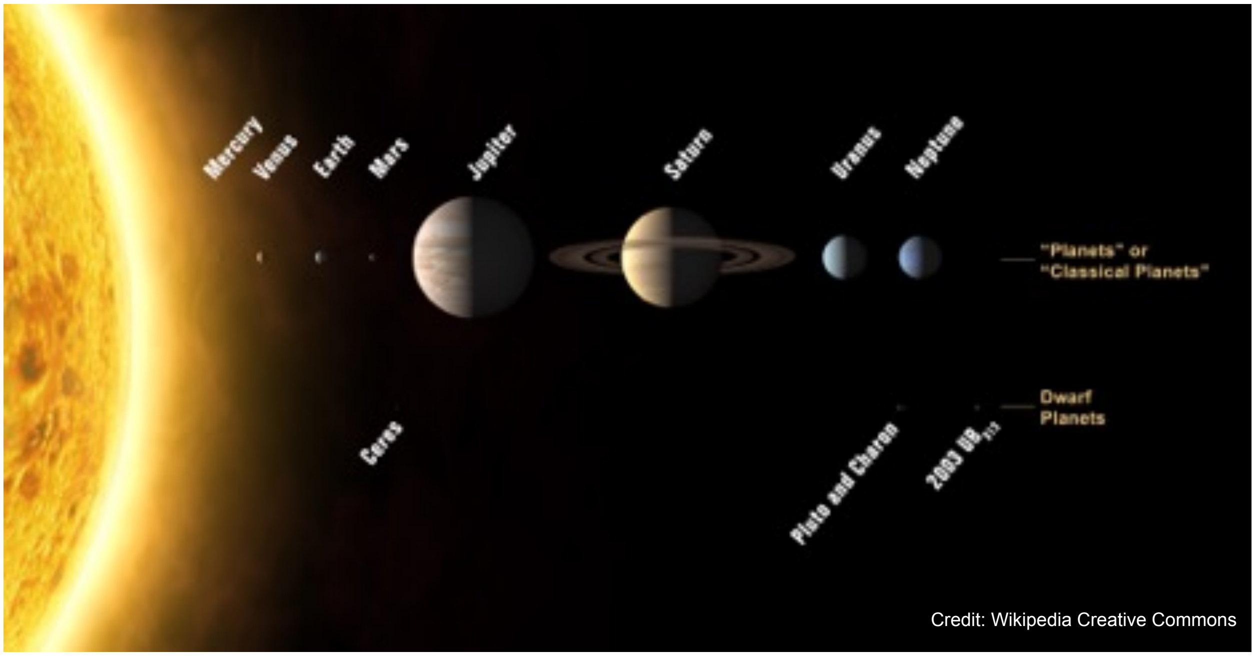
To Move Forward, We Have To Leave Something Behind

After the story of Copernicus through Galileo, the dominant question was, why are Kepler's laws true? How come there are ellipses? How come equal area and equal time? How come Period squared is average distance cubed? What makes these true empirical facts? Galileo and Kepler thought that maybe it was magnetism, because they knew what magnetism was. You could find rocks that had magnets. So that seemed like a pretty good idea.

In this module well start the journey of answering these questions by covering Newton's laws of motion.

Credit: Wikipedia
Public Domain

By his own account, Isaac Newton experienced a moment of inspiration when he saw an apple fall to the ground. That was a Eureka moment, because he suddenly realized that whatever was making the apple fall was the same that held the moon in its orbit. The two were one in the same. He made up that whatever, and he called it gravity. This goes back to a quote that we had from Richard Feynman, where the first thing you do is you guess. And Newton called his guess gravity.



Credit: Wikipedia Creative Commons

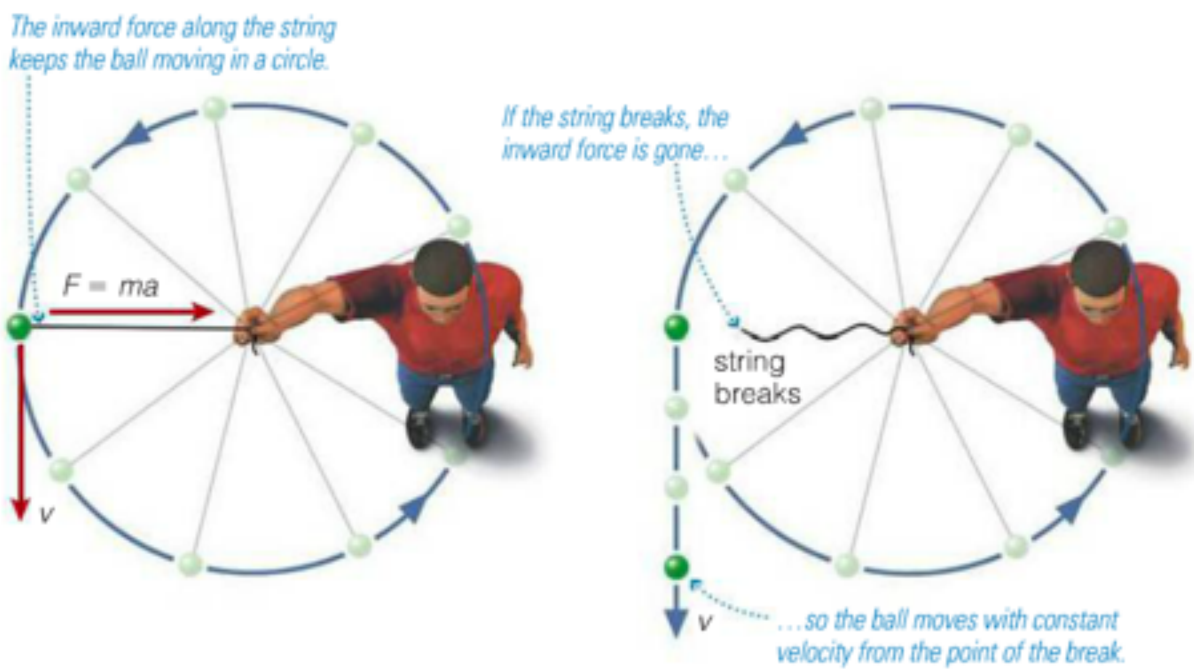
Fundamentally what Newton showed was that the same physical laws that operate on Earth -- what makes the apple fall -- is the exact same laws that make the moon orbit about Earth. If you discover a law on Earth, it holds throughout the cosmos. Powerful stuff.

Credit:NASA

So Newton's first law is - - an object at rest remains at rest, and an object in motion remains in motion along a straight line unless acted on by a force. OK? It's the "along a straight line" part that is important. It doesn’t say in a circle, or along any curved path. Along a straight line. Remember that. Yes It will be on the test.

Newton’s first law is important philosophically because it says that a force changes motion. This is very different than what Aristotle taught, which was that no force means no motion. If you have a ball, and you put a ball on a table, you know that if you want to make the ball move, you have to apply a force to it. And the ball moves. Eventually the ball slows down, and it stops. So by Aristotle, the natural state of motion was to stop, was to be at rest. If you wanted to make something move, you had to apply force to it, to make it. Aristotle’s view totally agrees with your everyday experience.

What's different here is that we now know that there's a force associated with the roughness of the table or the roughness of the object . This force, this dissipative force, this frictional force, causes the ball to slow down and stop. The frictional force acting on the ball changes its motion. Without that friction force, that ball would just keep going and going and going along a straight line without ever stopping. The only thing that's going to change motion is a force.



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Here's another example. You can demonstrate the "along a straight line" bit of Newton's first law by taking a ball, putting it on a string and spinning it around over your head, like in the figure above on the left. To make the analogy transparent here, the orbit is a circle and the tension in the string is playing the role of something we're going to call gravity.

Now suppose the string breaks as shown in the right part of the image above. What happens? Well, you know what happens. The ball goes off in a straight line. The ball doesn't keep going around the circle, right? The ball flies off in a straight line, as though it was a hammer throw at the Olympics. Those athletes spin around with that heavy ball at the end, they let go, and what does the hammer do? It goes off in a straight line -- Newton's first law. So an object in motion remains in motion along a straight line, unless acted on by a force.

Credit:NASA

Newton's second law says the change of an object's motion is proportional to the force and in the direction of the force. This wild new idea is summarized by the equation that the force is equal to the mass times the acceleration. We've introduced the concept of acceleration and mass. A mass is basically how many atoms are in an object, and the acceleration is a change in the velocity. So a force is defined to be equal to a mass times acceleration.

A force always acts in the direction of the change in the motion, not in the direction of motion. Read that sentence again. If I have a ball moving on a table, I have to push in the direction where I want the ball to go. The force is in the change in the direction. So a force makes changes.

Credit:NASA

Newton's third is a simple statement that for every force, there is an equal and opposite force. You experience this daily when you walk or you jump. Say you're on the surface of the Earth and you jump up. You push down on Earth and Earth pushes up on you. You go up, the Earth goes down. But the Earth is seriously much more massive than you are. So the Earth hardly moves at all. But there is an equal and opposite force. Same thing with a rocket. When a rocket fires, gases are expelled out the back end. The rocket responds with an equal and opposite reaction - it moves forward.

One of my favorite paraphrases of Newton’s third law comes from the movie Interstellar. In order to escape the wormhole with enough fuel to get home, the protagonist Copper bails out the back of the spaceship telling the remaining crew member “To move forward, we have to leave something behind.” This is how all rockets work.

Sometimes people get all twisted up in logical knots; if for every force there's an equal and opposite force, then how does anything ever move? Don't get all confused by it. It's really quite simple and beautiful.

Thanks! Bye Bye.