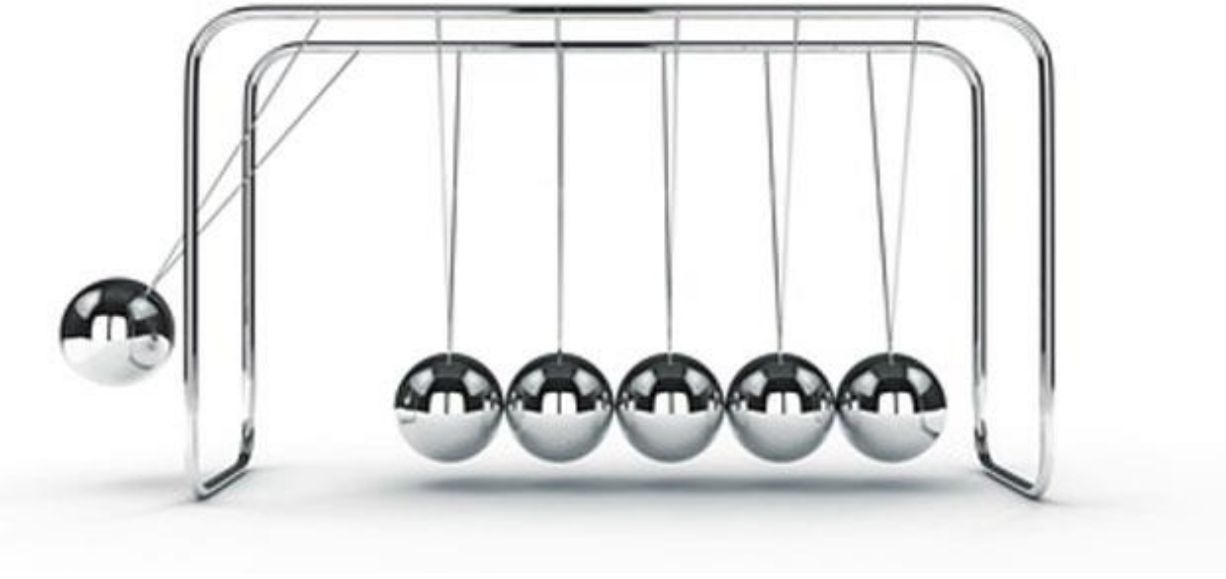
Isaac Newton's

Laws of Motion

With brief explanations of the Law of Gravity and Einstein's Theory of Relativity



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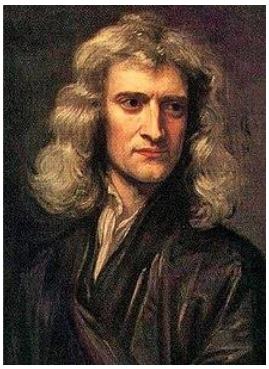
Isaac Newton



Sir Isaac Newton PRS (25 December 1642 – 20 March 1727) was an English mathematician, physicist, astronomer, theologian, and author (described in his own day as a "natural philosopher") who is widely recognized as one of the most influential scientists of all time, and a key figure in the scientific revolution. Isaac Newton came up with three Laws of Motion to describe how things move scientifically. He also described how gravity works, which is an important force that affects everything.

Isaac Newton is considered one of the most important scientists in history. Even Albert Einstein said that Isaac Newton was the smartest person that ever lived. During his lifetime Newton developed the theory of gravity, the laws of motion (which became the basis for physics), a new type of mathematics called calculus, and made breakthroughs in the area of optics such as the reflecting telescope.
Isaac attended school where he was an adequate student. At one point his mother tried to take him out of school so he could help on the farm, but Isaac had no interest in becoming a farmer and was soon back at school.

Isaac grew up mostly alone. For the rest of his life he would prefer to work and live alone focused on his writing and his studies.

In 1661, Isaac began to attend college at Cambridge. He would spend much of his life at Cambridge, becoming a professor of mathematics and a fellow of the Royal Society (a group of scientists in England). He eventually was elected to represent Cambridge University as a member of parliament.

Isaac had to leave Cambridge from 1665 to 1667 because of the Great Plague. He spent these two years in study and isolation at his home in Woolsthorpe developing his theories on calculus, gravity, and the laws of motion.

In 1696 Newton became the warden of the Royal Mint in London. He took his duties seriously and tried to get rid of corruption as well as to reform the currency of England. He was elected President of the Royal Society in 1703 and was knighted by Queen Anne in 1705.

The Principia In 1687 Newton published his most important work called the *Philosophiae Naturalis Principia Mathematica* (which means "Mathematical principals of Natural Philosophy"). In this work he described the three laws of motion as well as the law of universal gravity. This work would go down as one of the most important works in the history of science. It not only introduced the theory of gravity, but defined the principals of modern physics.

Scientific Discoveries Isaac Newton made many scientific discoveries and inventions throughout his career. Here is a list of some of the most important and famous ones.

- Gravity - Newton is probably most famous for discovering gravity. Outlined in the Principia, his theory about gravity helped to explain the movements of the planets and the Sun. This theory is known today as Newton's law of universal gravitation.
- Laws of Motion - Newton's laws of motion were three fundamental laws of physics that laid the foundation for classical mechanics.
- Calculus - Newton invented a whole new type of mathematics which he called "fluxions." Today we call this math calculus and it is an important type of math used in advanced engineering and science.
- Reflecting Telescope - In 1668 Newton invented the reflecting telescope. This type of telescope uses mirrors to reflect light and form an image. Nearly all of the major telescopes used in astronomy today are reflecting telescopes.

Legacy Newton died on March 31, 1727 in London, England. Today, he is considered one of the most influential scientists of all time alongside greats such as Albert Einstein, Aristotle, and Galileo.

Interesting Facts about Isaac Newton

- He studied many classic philosophers and astronomers such as Aristotle, Copernicus, Johannes Kepler, Rene Descartes, and Galileo.
- Legend has it that Newton got his inspiration for gravity when he saw an apple fall from a tree on his farm.
- He wrote his thoughts down in the Principia at the urging of his friend (and famous astronomer) Edmond Halley. Halley even paid for the book's publication.
- He once said of his own work "If I have seen further than others, it is by standing upon the shoulders of giants."

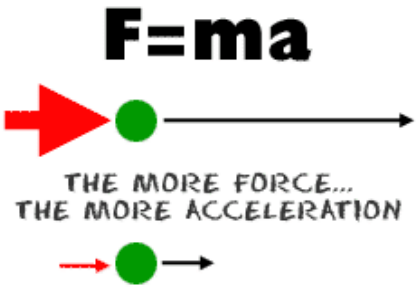
Newton's Three Laws of Motion

1. **Law of Inertia: An object in motion will remain in motion unless an external force acts on it.** The first law says that an object at rest tends to stay at rest, and an object in motion tends to stay in motion with the same direction and speed. *(first pioneered by Galileo)*

2. **Force equals mass times acceleration**
   The second law shows that if you exert the same force on two objects of different mass, you will get different accelerations (changes in motion).

   F = m*a or F = ma

   *An * sometimes represents a multiplication symbol.*
   An X would not be used since mathematical letters are used.
   Two letters next to each other can also mean to multiply.



3. **For every action there is an equal and opposite reaction.**

TERMS:

Mass:	A measurement of how much matter is in an object. It is usually measured in kilograms. A coherent, typically large body of matter with no definite shape.
Force:	Force is the measurement of a push or pull on an object. Force is a vector measured in newtons. Strength or energy as an attribute of physical action or movement.
Velocity:	The speed of something in a given direction. The rate of change in an object's position. Velocity is a vector quantity. The magnitude of velocity is the object's speed.
Inertia:	A tendency to do nothing or to remain unchanged.
Motion:	The action or process of moving or being moved.

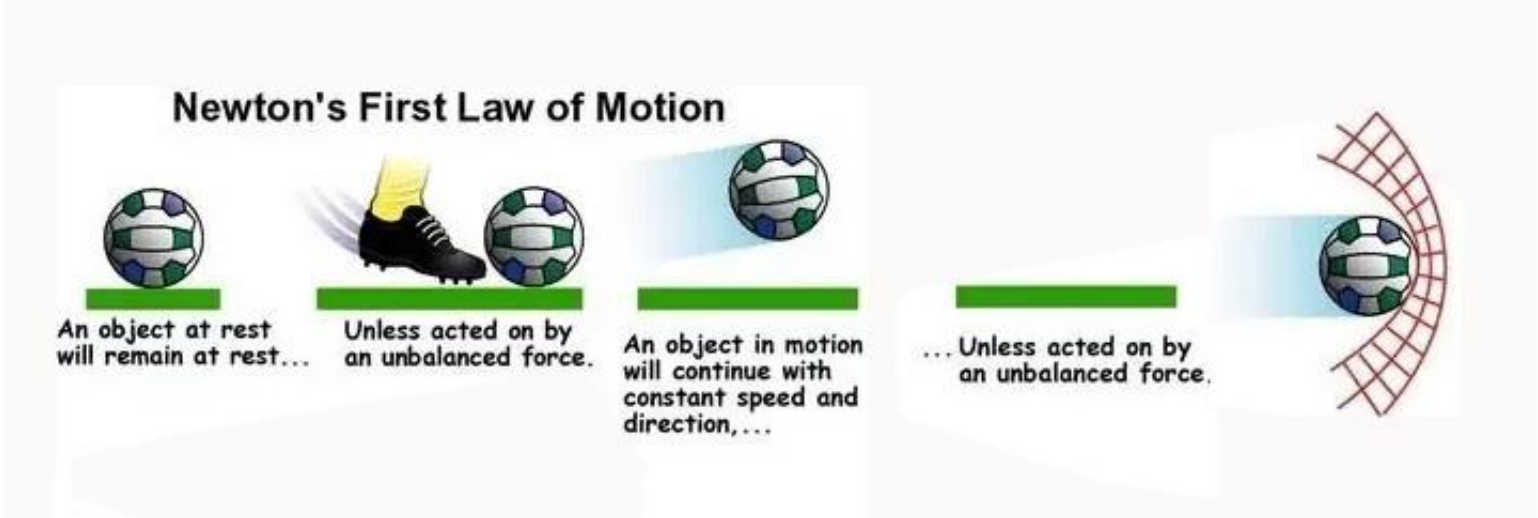
1st Law of Motion

Any object in motion will continue to move in the same direction and speed, unless external forces act on it.

The First Law of Motion states, "A body at rest will remain at rest, and a body in motion will remain in motion unless it is acted upon by an external force." This simply means that things cannot start, stop, or change direction all by themselves. It takes some force acting on them from the outside to cause such a change. This property of massive bodies to resist changes in their state of motion is sometimes called *inertia*.

The first law says that an object at **rest** tends to stay at rest, and an object in **motion** tends to stay in motion, with the same direction and **speed**. Motion (or lack of motion) cannot change without an unbalanced **force** acting. If nothing is happening to you, and nothing does happen, you will never go anywhere. If you're going in a specific direction, unless something happens to you, you will always go in that direction. Forever.

You can see good examples of this idea when you see video footage of **astronauts**. Have you ever noticed that their tools float? They can just place them in space and they stay in one place. There is no interfering force to cause this situation to change. The same is true when they throw objects for the camera. Those objects move in a straight line. If they threw something when doing a spacewalk, that object would continue moving in the same direction and with the same speed unless interfered with; for example, if a planet's **gravity** pulled on it (Note: This is a really really simple way of describing a big idea. You will learn all the real details - and math - when you start taking more advanced classes in physics.).



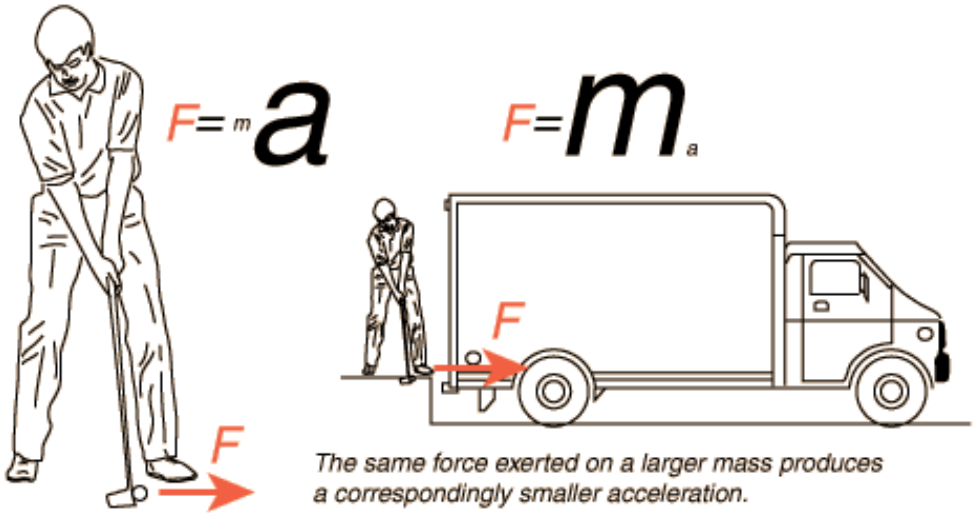
2nd Law of Motion

The greater the mass of an object, the more force it will take to accelerate the object

The Second Law of Motion describes what happens to a massive body when it is acted upon by an external force. It states, "The force acting on an object is equal to the mass of that object times its acceleration." This is written in mathematical form as **F** = *m***a**, where **F** is force, *m* is mass, and **a** is acceleration. The bold letters indicate that force and acceleration are *vector* quantities, which means they have both magnitude and direction. The force can be a single force, or it can be the vector sum of more than one force, which is the net force after all the forces are combined.

When a constant force acts on a massive body, it causes it to accelerate, i.e., to change its velocity, at a constant rate. In the simplest case, a force applied to an object at rest causes it to accelerate in the direction of the force. However, if the object is already in motion, or if this situation is viewed from a moving reference frame, that body might appear to speed up, slow down, or change direction depending on the direction of the force and the directions that the object and reference frame are moving relative to each other.

The second law says that the **acceleration** of an object produced by a net (total) applied force is directly related to the **magnitude** of the force, the same direction as the force, and inversely related to the mass of the object (inverse is a value that is one over another number... the inverse of 2 is 1/2). The second law shows that if you exert the same force on two objects of different mass, you will get different accelerations (changes in motion). The effect (acceleration) on the smaller mass will be greater (more noticeable). The effect of a 10 newton force on a baseball would be much greater than that same force acting on a truck. The difference in effect (acceleration) is entirely due to the difference in their masses.



The same force exerted on a larger mass produces a correspondingly smaller acceleration.

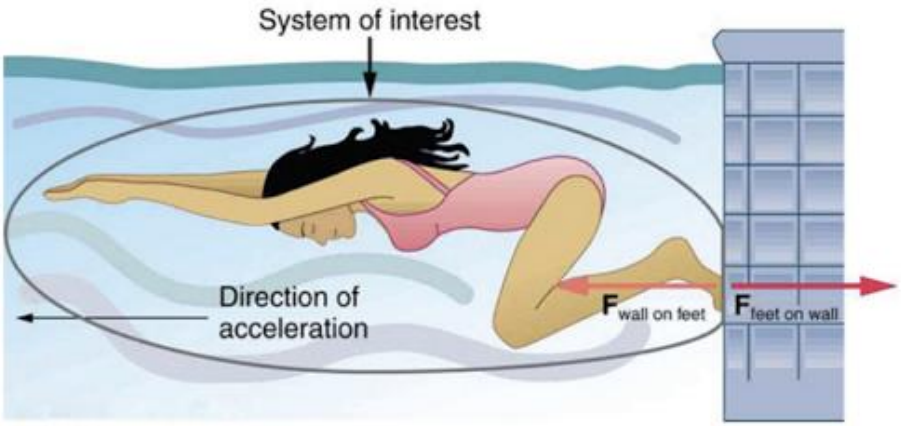
3rd Law of Motion -

For every action there is an equal and opposite reaction

The Third Law of Motion states, "For every action, there is an equal and opposite reaction." This law describes what happens to a body when it exerts a force on another body. Forces always occur in pairs, so when one body pushes against another, the second body pushes back just as hard. For example, when you push a cart, the cart pushes back against you; when you pull on a rope, the rope pulls back against you; when gravity pulls you down against the ground, the ground pushes up against your feet; and when a rocket ignites its fuel behind it, the expanding exhaust gas pushes on the rocket causing it to accelerate.

If one object is much, much more massive than the other, particularly in the case of the first object being anchored to the Earth, virtually all of the acceleration is imparted to the second object, and the acceleration of the first object can be safely ignored. For instance, if you were to throw a baseball to the west, you would not have to consider that you actually caused the rotation of the Earth to speed up ever so slightly while the ball was in the air. However, if you were standing on roller skates, and you threw a bowling ball forward, you would start moving backward at a noticeable speed.

The third law says that for every action (force) there is an equal and opposite reaction (force). Forces are found in pairs. Think about the time you sit in a chair. Your body exerts a force downward and that chair needs to exert an equal force upward or the chair will collapse. It's an issue of symmetry. Acting forces encounter other forces in the opposite direction. There's also the example of shooting a cannonball. When the cannonball is fired through the air (by the explosion), the cannon is pushed backward. The force pushing the ball out was equal to the force pushing the cannon back, but the effect on the cannon is less noticeable because it has a much larger mass. That example is similar to the kick when a gun fires a bullet forward.



The three laws have been verified by countless experiments over the past three centuries, and they are still being widely used to this day to describe the kinds of objects and speeds that we encounter in everyday life. They form the foundation of what is now known as *classical mechanics*, which is the study of massive objects that are larger than the very small scales addressed by quantum mechanics and that are moving slower than the very high speeds addressed by relativistic mechanics.

RECAP….

First Law of Motion

The first law says that any object in motion will continue to move in the same direction and speed unless forces act on it.

That means if you kick a ball it will fly forever unless some sort of forces act on it! As strange as this may sound, it's true. When you kick a ball, forces start to act on it immediately. These include resistance or friction from the air and gravity. Gravity pulls the ball down to the ground and the air resistance slows it down.

Second Law of Motion

The second law states that the greater the mass of an object, the more force it will take to accelerate the object. There is even an equation that says Force = mass x acceleration or F=ma.

This also means that the harder you kick a ball the farther it will go. This seems kind of obvious to us, but having an equation to figure out the math and science is very helpful to scientists.

Third Law of Motion

The third law states that for every action, there is an equal and opposite reaction. This means that there are always two forces that are the same. In the example where you kicked the ball there is the force of your foot on the ball, but there is also the same amount of force that the ball puts on your foot. This force is in the exact opposite direction.

A force is anything that can change the state of motion of an object, like a push or a pull. You use force when you push a letter on the computer keyboard or when you kick a ball. Forces are everywhere. Gravity acts as a constant force on your body, keeping you secure on planet Earth so you don't float away.

To describe a force we use the direction and strength. For example when you kick a ball you are exerting force in a specific direction. That is the direction the ball will travel. Also, the harder you kick the ball the stronger the force you place on it and the farther it will go.

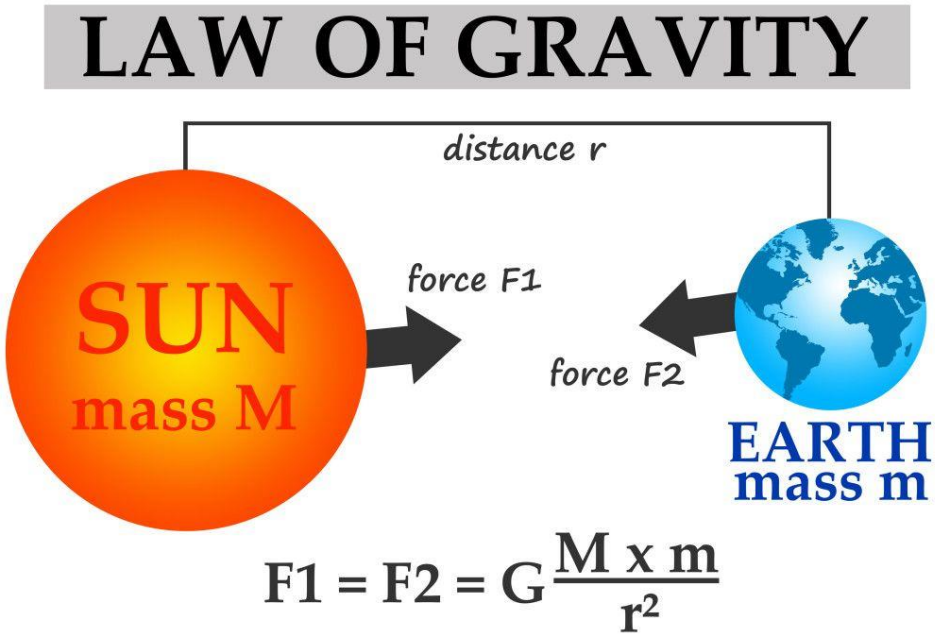
Fun facts about Forces and Motion

- It is said that Isaac Newton got the idea for gravity when an apple fell off a tree and hit him on the head.
- Forces are measured in Newtons. This is after Isaac Newton, not fig newtons, even if they are tasty.
- Gases and liquids push out in equal forces in all directions. This is called Pascal's Law because it was discovered by the scientist Blaise Pascal.
- When you go upside down in a roller coaster loop-the-loop, a special kind of force called "centripetal force" keeps you in your seat and from falling out.

Newton’s Law of Gravity

Law of Universal Gravitation

Newton's **law of universal gravitation** states that every particle attracts every other particle in the universe with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers.

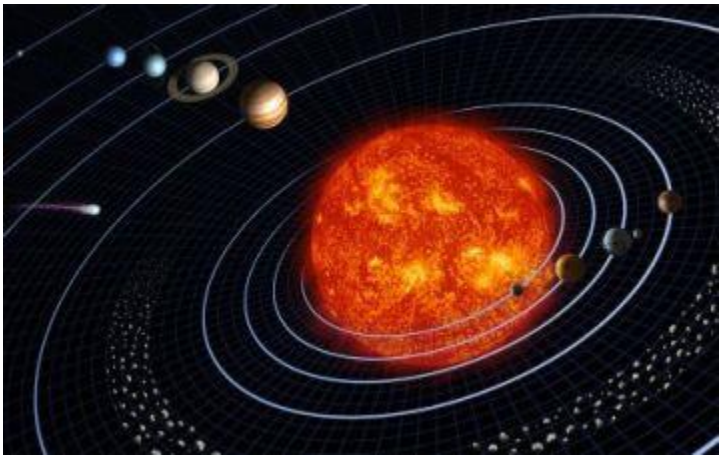


Gravity is the mysterious force that makes everything fall down towards the Earth.
But what is it?

It turns out that all objects have gravity. It's just that some objects, like the Earth and the Sun, have a lot more gravity than others.

How much gravity an object has depends on how big it is. To be specific, how much mass it has. It also depends on how close you are to the object. The closer you are, the stronger the gravity.

Gravity is very important to our everyday lives. Without Earth's gravity we would fly right off it. We'd all have to be strapped down. If you kicked a ball, it would fly off forever. While it might be fun to try for a few minutes, we certainly couldn't live without gravity.



Gravity also is important on a larger scale. It is the Sun's gravity that keeps the Earth in orbit around the Sun. Life on Earth needs the Sun's light and warmth to survive. Gravity helps the Earth to stay just the right distance from the Sun, so it's not too hot or too cold.

Who discovered gravity?

The first person who dropped something heavy on their toe knew something was going on, but gravity was first mathematically described by the scientist Isaac Newton. His theory is called *Newton's law of universal gravitation*. Later, Albert Einstein would make some improvements on this theory in his *theory of relativity*.

What is weight?

Weight is the force of gravity on an object. Our weight on Earth is how much force the Earth's gravity has on us and how hard it is pulling us toward the surface.

Do objects fall at the same speed?

Yes, this is called the equivalence principle. Objects of different masses will fall to the Earth at the same speed. If you take two balls of different masses to the top of a building and drop them, they will hit the ground at the same time. There is actually a specific acceleration that all objects fall at called a standard gravity, or "g". It equals 9.807 meters per second squared (m/s^2).

Fun facts about gravity

- Ocean tides are caused by the gravity of the moon.
- Mars is smaller and has less mass than Earth. As a result it has less gravity. If you weigh 100 pounds on Earth, you would weigh 38 pounds on Mars.
- The standard gravity from Earth is 1 g force. When riding a roller coaster you may feel a lot more g forces at times. Maybe as much as 4 or 5 g's. Fighter pilots or astronauts may feel even more.
- At some point when falling, the friction from the air will equal the force of gravity and the object will be at a constant speed. This is called the terminal velocity. For a sky diver this speed is around 122 miles per hour!

Gravity In Space

Satellites are kept in orbit by gravity.

Gravity is a force that attracts objects toward other objects. This force affects everything here on Earth. It even controls objects in outer space!

First, let's think about the big picture. If it weren't for gravity, we wouldn't have a planet to live on. The sun's gravity keeps Earth in its **orbit**, or path, around the sun. If the sun's gravitational force changed, the earth might get too close or too far from the sun to support life! It's not just Earth that depends on the sun's gravity, either. All the planets, moons, asteroids, meteors, comets, and other objects in our solar system are also affected by the gravity of the sun.

You might think that the earth is kind of like a puppet being controlled by the sun. Well, Earth is powerful, too! Did you know Earth's own gravity keeps the moon in orbit? It also keeps the **satellites** in orbit that send communication signals to the earth. We depend on those satellites to use cell phones! So if you have a cell phone, you have gravity to thank for being able to send texts to your friends!

Gravity In Nature

The ocean tides are caused by gravitational forces from the sun and moon.

OK, now let's talk about gravity here on Earth. All you have to do is take a look at the great outdoors to see how gravity affects our environment. Think about squirrels scurrying around looking for food. The earth's gravitational force is pulling those squirrels towards the center of the earth, allowing them to stay on the ground and find their precious acorns. That reminds me -- how do acorns get on the ground? They fall from a tree, right? Well, gravity causes acorns to fall to the ground. I guess squirrels have gravity to thank, too!

You'll never believe what else is controlled by gravity -- the oceans' tides! **Tides** are the rise and fall of the sea level on the coastlines of the world. Both the sun's gravity and the moon's gravity play a part in creating high and low tides here on Earth. Wow!

Einstein's Theory of Relativity

Albert Einstein made improvements on Newton's Law of Universal Gravitation with his Theory of Relativity.

Special relativity says that motion is always relative and that space and time exist in relation to each other.

General relativity states that planets bend space and time the way a bowling ball bends a trampoline.

The **THEORY OF RELATIVITY** is a scientific explanation about how space relates to time. The theory of relativity is very important for scientists studying outer space and how the universe works.

Special relativity says that motion is always relative. Imagine a baseball floating alone in empty space. How do you know if it's moving or not? You can't. But if you put a basketball in space with the baseball, you could see whether the baseball was getting closer to the basketball or further away from it. Then you could see if the baseball was moving.

That's why it's called 'relativity.' The motion of one thing is always relative to the motion of everything else.

Special relativity also says that light always travels at the same speed, 186,000 miles per second. So in one second, light could travel all the way around the planet Earth about seven and a half times!

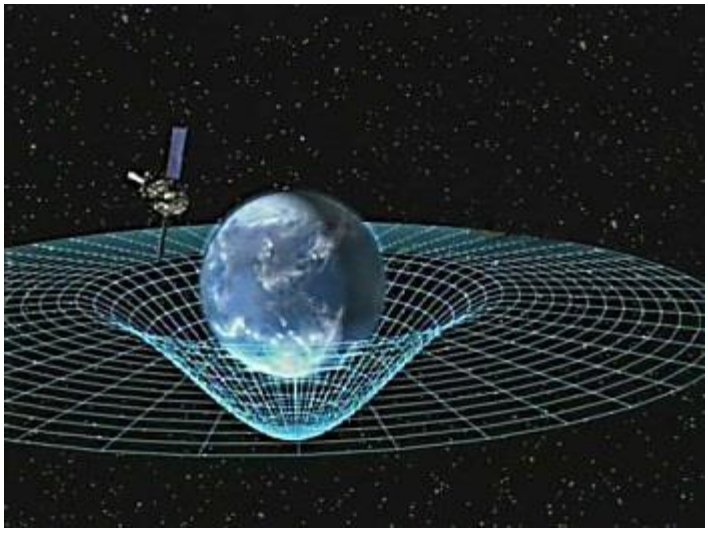
Now here's the weird part. Special relativity also says that space and time are connected. Time can actually speed up if you're moving slowly through space, or slow down if you're moving quickly. Together, space and time are called space-time. Space-time is like a giant trampoline that can 'bend' around big things like planets and stars.

Special relativity also says that mass, or the total amount of stuff in an object, can change depending on the speed of the object. If you started moving very fast, you would actually have more mass than you do right now.

There are two main ideas that make up Einstein's theory of special relativity.
1. The principle of relativity: The laws of physics are the same for any inertial reference frame.
2. The principle of the speed of light: The speed of light in a vacuum is the same for all observers, regardless of their relative motion or the motion of the source of the light.

General Relativity explains why things fall towards the ground when you drop them.

General relativity says that space-time is like a big trampoline. Imagine taking a big trampoline, and putting a heavy bowling ball on it. The bowling ball would make a dip in the trampoline and make the trampoline bend down.



The Earth in space-time looks like a bowling ball on a trampoline.

Gravity - Quiz

1) How much gravity an object has depends on its _____.

- Weight
- Speed
- Momentum
- Mass
- Acceleration

2) Which of the following has the strongest gravitational pull?

- A bowling ball
- A car
- The Earth
- The planet Mars
- The Sun

3) When will gravity be the strongest?

- The further away you are from an object
- The closer you are to an object
- The faster your relative speed is to an object
- All of the above
- None of the Above

4) True or False: Gravity helps the Earth to stay in orbit around the Sun.

- TRUE
- FALSE

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5) What scientist is credited with first describing the mathematics of gravity?

- Thomas Edison
- Alexander Graham Bell
- Isaac Newton
- Bill Gates
- Leonardo da Vinci

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6) What do we call the force of gravity on an object?

- Weight
- Mass
- Speed
- Acceleration
- Velocity

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7) True or False: The more mass an object has, the faster it will fall.

- TRUE
- FALSE

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8) What natural phenomena occurs on Earth due to the gravity of the Moon?

- Earthquakes
- Hurricanes
- Volcanic eruptions
- Thunder storms
- Ocean tides

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9) Where would you weigh the most?

- Mars
- Pluto
- Earth
- The Sun
- The Moon

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10) True or False: How much we weigh on Earth is a direct result of the force of the Earth's gravity.

- TRUE
- FALSE

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http://www.physics4kids.com/files/motion_laws.html

https://www.ducksters.com

https://www.quora.com/Is-Newtons-First-Law-of-Motion-related-to-inertia

https://www.khanacademy.org/science/physics/forces-newtons-laws/newtons-laws-of-motion/a/what-is-newtons-third-law

http://hyperphysics.phy-astr.gsu.edu/hbase/Newt.html

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