



## Forces of the Universe

Hello Galaxy Explorers. Today our mission is to understand the forces of the universe. In order to understand the forces of our universe, we must understand what makes up the universe. All around you can see the physical makeup of the universe – the rocks, trees, air, and water – all these are made up of matter. But what keeps the matter together? What prevents the rocks and trees from floating off into space? What keeps the atoms of a molecule from falling apart? The answer is force. Understanding all of the forces involved in the universe is critical to understanding the universe as a whole.

There are four known types of forces that interact with matter to define our universe. They are the strong, weak, electromagnetic, and gravitational forces.

The following table shows an overview of the four forces. You don't have to understand all the math here. Just note that there are four forces – each with different strengths:

<i>Strong</i>		Force which holds nucleus together <b>1</b>	Range (m) $10^{-15}$ (diameter of a medium sized nucleus)	Particle $\pi$ , others mass > 0.1 GeV
<i>Electromagnetic</i>		Strength $\frac{1}{137}$	Range (m) Infinite	Particle photon mass = 0 spin = 1
<i>Weak</i>		Strength $10^{-5}$	Range (m) $10^{-17}$ (0.1% of the diameter of a proton)	Particle Intermediate vector bosons $W^+$ , $W^-$ , $Z^0$ , mass > 80 GeV spin = 1
<i>Gravity</i>		Strength $6 \times 10^{-39}$	Range (m) Infinite	Particle graviton? mass = 0 spin = 2

\* Table from <http://hyperphysics.phy-astr.gsu.edu/hbase/forces/funfor.html#c1>

### Gravitational Force

Gravity is a force that we interact with every day. It is responsible for keeping your feet on the ground and for bringing a baseball back down when thrown or hit. It is also responsible for the moon orbiting the earth, the earth orbiting the sun, and keeping galaxies together.

Gravity is present wherever matter is present. Gravity is the weakest of the four forces. However, the more matter that is present, the stronger the gravitational force is. And gravity works over very great distances – trillions and trillions of miles. An individual atom contains a very small amount of matter, and therefore the gravitational force from it is very tiny. A very large object, like the Earth, has an enormous amount of mass and therefore has a very strong gravitational force. It is the combined gravitational pull from all the atoms in the Earth that pulls you, the moon, and baseballs to the ground.

### Weak Force

Despite the name, the Weak force is actually  $10^{34}$  (10 million trillion trillion) times stronger than gravity. The weak force exists deep inside the nucleus, or center, of atoms. It is responsible for determining if an element will be a proton, electron, or neutron. The weak force has a very small range, so it is not visible in our every day lives. However, without the weak force, the universe could not exist as it does. Stars could not shine and elements heavier than iron would not exist.

### Electromagnetic Force

The Electromagnetic force is also present in our everyday lives. The magnets on your refrigerator, engines in your car, and all electronic devices use Electromagnetic force. It is the second strongest of the four forces.

The roots of Electromagnetism, like Gravity, can be traced to the atom. Atoms contain tiny particles that have a property called ‘charge’. There are two types of charge; ‘negative’ charge is a property of electrons, and ‘positive’ charge is a property of protons. The interactive force between these two charges is Electromagnetism. Opposite (that is, negative and positive) charges attract (or pull towards) each other, and like (that is positive and positive, or negative and negative) charges repel (or push away from) each other. This is different than Gravity, which always attracts. Like Gravity, many electrons together can combine to produce a strong negative electromagnetic force, and many protons together can combine to produce a strong positive electromagnetic force.

The Electromagnetic force is about 1000 times stronger than the weak force. If you take a penny and separate its electrons from its protons, and put each half on opposite sides of the earth, the force between them would equal 120 tons! The force due to Gravity between them would be almost undetectable.

### A note about Magnets

It was once thought that magnetism was a different force than the electric force. However, it was later discovered that magnetic force is actually due to an alignment of atoms in a metal. This is because when a charge moves, it creates a magnetic field. Since atoms have many electrons (or negative charges) in motion around the nucleus, they create miniature magnetic fields. Normally, the atoms are arranged randomly so the total magnetic field from all of them is 0. However, when all the atoms are aligned (that is, all electrons are spinning in the same direction), all the little magnetic fields together create a big magnetic field that can be detected. This is what happens in magnets, because all of the atoms are aligned.

### Strong Force

The center of an atom, the nucleus, is made up of protons and neutrons. Protons have a positive charge, and neutrons have no charge at all. This means that, in the nucleus, there are many positive charges sticking together. If you remember from Electromagnetism, like charges repel each other. What keeps the protons from flying apart? The answer is the 'Strong' force.

The Strong force, as the name implies, is the strongest of the four forces. It is a very powerful force that binds the nucleus of an atom together. There is a large amount of energy stored in this force. This is where nuclear energy comes from. When an atom's nucleus is split, the energy stored by the Strong binding force is released. This energy is then converted to electricity. A small amount of atoms contain a very large amount of energy stored in the Strong force holding the atom together.

### Force Fields

All forces act upon an object in a particular direction. For example, gravity pulls objects in a straight line towards the center of the object creating the gravity. Electromagnetic forces go from the positive charge to the negative charge (North Pole to the South Pole for magnets). The patterns created by these are called Force Fields. Basically, the lines in a force field describe how an object will move when placed near an object that emits a force.

### The Unified Theory

For many years, scientists have been trying to find a way to tie the four forces together into one theory. This is called the 'Unified' theory. To date, there has been no way to tie the four forces together. It is hoped that one day this Unified theory will be found and simplify the way we look at the universe.

### Activity #1 – Electromagnetism

Supplies: A magnet, some iron filings, a sheet of white paper.

Place some iron filings on a sheet of white paper. Spread them out evenly on the paper. Note how they are arranged randomly. Next, place a magnet underneath the paper.

Notice how the filings line up. The electromagnetic force is affecting the filings. The lines they create from North to South poles of the magnet describe the magnetic field.

Experiment by arranging the magnet in different positions under the paper and note how the lines change, showing how the force field changes.

Activities

Activity #2 – Gravity

Supplies: A rubber bouncing ball, a stop watch, a yard stick

All forces produce an acceleration on an object according to Newton’s Second Law (Force = mass \* acceleration). This means that gravity will cause an object to accelerate. This acceleration can be found by measuring how long it takes for an object to fall a certain distance.

To calculate the acceleration due to gravity, try the following:

1. Measure a height 2 feet, 4 feet, and 6 feet above the ground
2. Drop a ball from each height
3. Using the stopwatch, measure the time it takes for the ball to hit the ground (start when the ball is released, and stop when it hits the ground).
4. Calculate the acceleration from the following formula:

$$\text{acceleration} = 2 * \text{height} / (\text{time}^2)$$

Take the measurements at each location three times, and then calculate the average acceleration.

Height	Time	Acceleration (feet/second <sup>2</sup> )
2 Feet (attempt #1)		
2 Feet (attempt #2)		
2 Feet (attempt #3)		
2 Feet (average)		
4 Feet (attempt #1)		
4 Feet (attempt #2)		
4 Feet (attempt #3)		
4 Feet (average)		
6 Feet (attempt #1)		
6 Feet (attempt #2)		
6 Feet (attempt #3)		
6 Feet (average)		

