FOUR FUNDAMENTAL FORCES

Gravity, E & M, Weak & Strong

To get a grasp of large powers of ten…(story time)

When I was in college … an Astronomy professor said, "There are more stars in the universe than all the grains of sand on all the beaches on Earth."

So in 1997…when I started looking for ways to make my Astronomy class more exciting … I decided to figure out how many grains of sand on all the beaches and how many stars in the universe…

After a short period of thinking … I realized that I did not know what beach depths were around the world (Key West beaches non-existent but large island of Hawaii has great beaches north of Kona)… so I upped the ante to grains of sand to fill a sphere the size of planet Earth…now let's see if the stars can still win…

Calculating How Many Grains of Sand to Fill Planet Earth: (magnitude 10^{30})

Having students line up grains of sand on a cm line segment they drew and counting how many in a cm (about 20 on avg.) we realized there were 400 grains of sand in a sq. cm and 8000 grains of sand in a cc.

The calculation of grains of sand to fill a sphere the size of planet Earth:

The equatorial radius of the Earth is 6,378 km. So taking the volume of a sphere is $4\pi r^3/3$ and plugging in the radius gives a volume of the Earth to be about 1×10^{21} m^3 or 1×10^{27} cm^3 times 8,000 grains of sand per cm^3 is 8×10^{30} average grains of sand to fill planet Earth.

Calculating How Many Stars in the Universe: (at least magnitude 10^{36})

After showing students both NASA's "Hubble Deep Sky Picture" and "Hubble Ultra Deep Sky Picture" where there are anywhere from 1,500 galaxies to 10,000 galaxies per Hubble field picture… and that a Hubble picture takes up the size of a grain of sand held on a finger raised to arm's length on Earth and realizing that the density of galaxies looking any direction from Earth has been proven to be the same; all one has to do is figure out the surface area of the Earth and do the following calculation to approximate the number of stars in the universe. Imagine having a sand box large enough to roll a sticky sphere the size of the Earth in… each grain of sand that stuck to the Earth would represent a Hubble Deep Field picture.

The Calculation of the minimum number of stars in the universe: (magnitude 10^{36})

Since the radius of the Earth is 6,378 km, the surface area is about 5.1 X 10^8 km^2 or 5.1 X 10^{18} cm^2. Taking the surface area of the Earth in sq. cm times the number of grains of sand (or Hubble Deep Field pictures) per sq. cm times the number of galaxies per Hubble Deep Field picture times how many stars in the average galaxy gives us how many starts in the universe.

Thus 5.1 X 10^{18} cm^2 X 4 X 10^2 grains or Hubble Deep Field pictures/cm^2 X 5 X 10^3 galaxies/Hubble Deep Field picture X 3 X 10^{11} stars per average galaxy gives a magnitude of 10^{36} minimum stars in the universe.

Two points to be made:

1). If there are 10^{30} grains of sand to fill a sphere the radius of the Earth and 10^{36} stars in the universe minimum…means that if you have some grains of sand in the palm of your hand and point to one grain… you can safely say there are at least one million stars in the universe to represent that grain and pointing to another grain say another million for this grain…etc. for every grain to fill a sphere the size of planet Earth.

2). Since there are at least a million stars for each grain of sand…that means naming a grain of sand after someone would be a million times more significant than naming a star after them.

End of Story

The Four Fundamental Forces in the Universe

Gravity is the weakest by far of the four forces but affects the largest distances. Gravity holds us and Moon to the Earth, the Earth to the Sun, the Sun to the Orion Arm, the Orion Arm to the Milky Way Galaxy, the Milky Way Galaxy to the at least 54 galaxies in the Local Group, and the Local Group to the at least 100 galaxy clusters in the Virgo Super Cluster of galaxies, and holds the super clusters of galaxies together as the universe expands.

The Weak Interaction Force is only effective at very small distances in the subatomic scale…at any larger scales the weak interaction force disappears. However, the Weak Interactive Force is a magnitude of 10^{25} stronger than the gravity force! The weak nuclear force, the fourth and last force to be discovered by physicists in the twentieth century, helps to turn protons into neutrons inside the sun, a necessary step in converting those protons into heavier elements like helium and releasing the radiant energy that makes its way to Earth. The weak force also acted billions of years ago inside exploding stars known as supernovas to make the elements such as oxygen and carbon found in our own bodies and other natural things on Earth.

The Electromagnetic Force is a magnitude 10^{36} stronger than gravity but the attractive and repulsive forces cancel themselves out so there are not huge concentrations of it. Where a positive and negative particle cancel themselves out … two hunks of mass coming double the

gravitational force. The E & M force is responsible for holding atoms together, for bonding atoms into molecules, for impelling the movement of electrons through wires in the form of electricity, and for light waves.

The Strong Force is a magnitude of 10^{38} stronger than the gravitational force but again is only effective at very very close sub-nucleic distances. If it wasn't for the strong force the positive charge in the nuclei would explode apart and only hydrogen would exist in the universe. In larger radius nuclei…the strong force dies off and is responsible for some kinds of radioactivity.

The End of Four Fundamental Forces