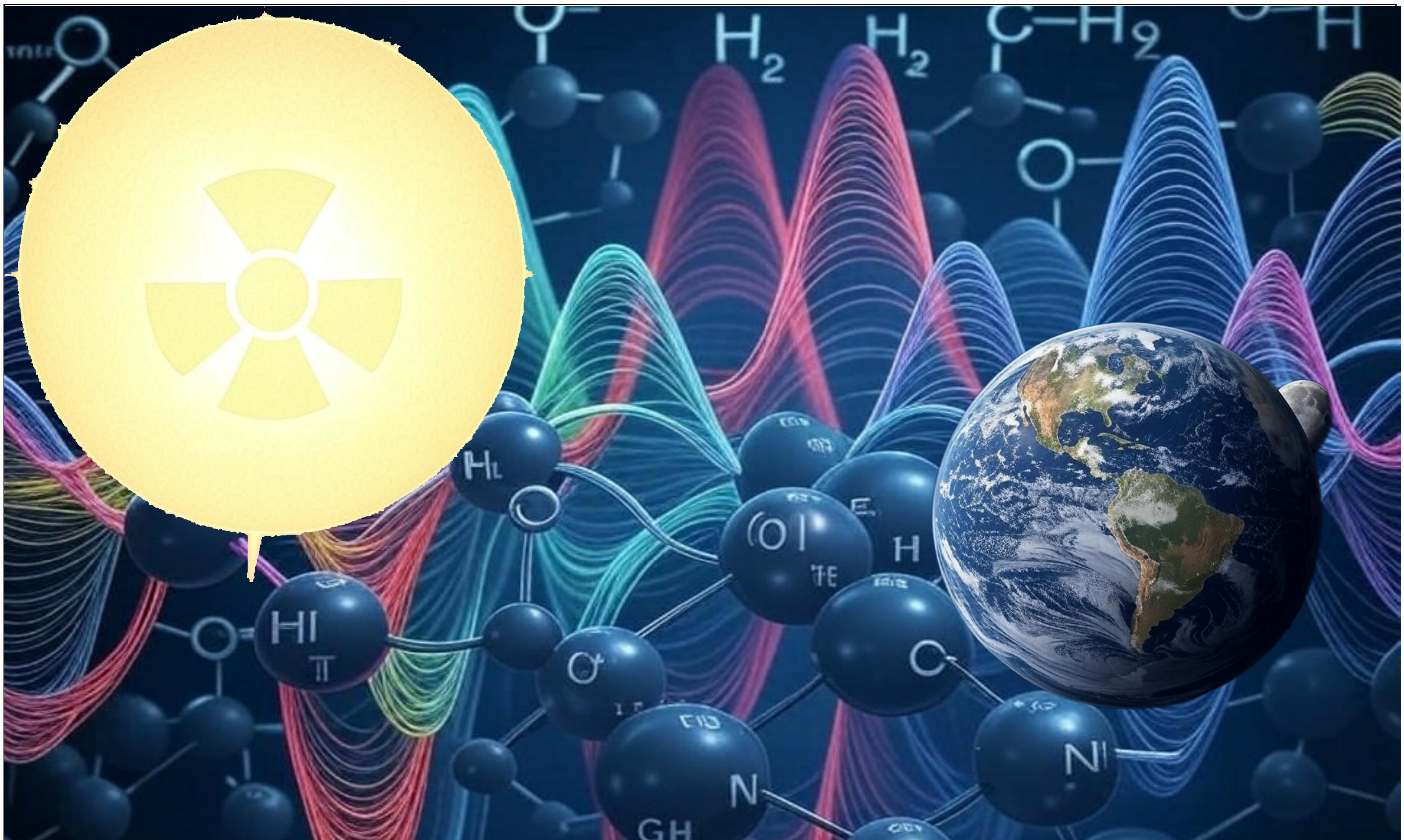


Understanding the Forces of Universe
GRAVITY

Empowering the Future of Engineering & Maintenance

Applied Electronics and Engineering

Hello!

The intent of this booklet is to leave you with clearing some related concepts, while igniting curiosity to generate more questions on how stuff works, by cultivating your inquiring faculty of mind. Hopefully! One question leading to another till you find satisfactory answers and able to connect all the dots to give yourself a meaningful solution in your mind.

The universe operates through a delicate balance of invisible forces that govern everything - from the fall of an apple to the nuclear fusion of stars. In this short journey, we unravel the four fundamental forces that shape reality: gravity, electromagnetic, weak nuclear, and strong nuclear. Each force plays a unique role, binding atoms, not only powering stars, and driving the cosmos but also impacts our day to day living. Without gravity, can we walk on floor?, drive cars?, we will not even have an atmosphere around earth to breath! Join us as we explore their mysteries and marvel at the unseen threads that weave the fabric of existence.

Understanding these governing forces around us will ultimately help you with more curiosity, seeking answers to your day to day work be it troubleshooting or designing or fixing something that is broken. You including me are not going to live forever, but there is theoretical way to live longer, find out how in this booklet.

Both metric and imperial based units will appear in this booklet, to get familiar with, again the intent is to clarify concepts, with whatever units that shows up.

An Exploration of Nature's Fundamental Forces - GRAVITY!

Atoms, like tiny solar systems with electrons (the planets) circling a nucleus (the sun), are held together by natures four big forces. These invisible forces around us are gravitational, electromagnetic, weak nuclear and strong nuclear. Let's talk about the nature's forces.

First, Gravity pulls things together, like Earth hugging the Moon. It comes from an objects mass (not weight, which is gravity's push felt on a mass.) Mass is just the "amount of matter" an object contains. The gravity pull of a mass on earth gives it a weight. In other words, the force of gravity on that mass is the weight. Then, how is mass measured? Easy answer is by determining it's weight. Really? Well, mass and weight are different concepts of matter. Mass is an intrinsic property and weight is extrinsic one influenced by the acting gravitational force. So, weight quantifies mass. Make sense?



Galileo Galilei, Henry Cavendish and Issac Newton appearing in the picture above in sequenced order played a vital role in defining and formulating the mass and gravity concepts.

Newtons second law states, the force acting on an object is equal to the inertial mass (m), a mass that loves inertia, of the object times its acceleration (a). F = m x a. When considering gravity it is F = m x g, where m is the gravitational mass and g is acceleration due to gravity. The inertial mass is nothing but the objects resistance to motion and stays in a place unless acted upon by an external force. Every objects or body on earth is pulled not only by earth's gravity but there are weak forces between those objects among themselves in the play as well.

A weighing balance measures the mass of an object by comparing the force of gravity on the mass in question to the force of gravity exerted on a reference mass (kept in France) and agreed upon internationally. Okay so far between mass and weight? Where does the gravitational pull come from, which property of mass drives the gravitational force. For sure it is not a magnet. Gravity in not just an earthly phenomenon. It is universal. Gravity is a fundamental force of universe that arises between objects containing mass. We will review this gravitational occurrence through studies made by Newton and Einstein.

Before we go further into relativity, let us learn the law the defines the gravity attraction between two masses in space at their respective frame of references. Both, the mass and the diameter of earth were calculated and known centuries ago and now perfected with newer technology. Let us take the published mass of earth as 5.9 x 10 raised to 24 kilograms, and diameter of earth as 12,742 kilometers. Given 24 hour day that we created, the speed of earth's rotation at the equator is about 1,600 kilometers/hour (1,000 miles/hour) and we do not feel it as it is smooth ride!

Newton, besides his three famous laws, also formulated the law of universal gravitation that states F = Gm1m2/r2. Where G is a universal gravitational constant which was derived by Henry Cavendish with the value 6.674×10 raised to –11 m3/kg x s2, m1 is the mass of earth, m2 is the mass of object in earth's gravity, r is the distance between center of the earth and the center of the object and F is the gravitational force in Newtons, a unit of measurable force.

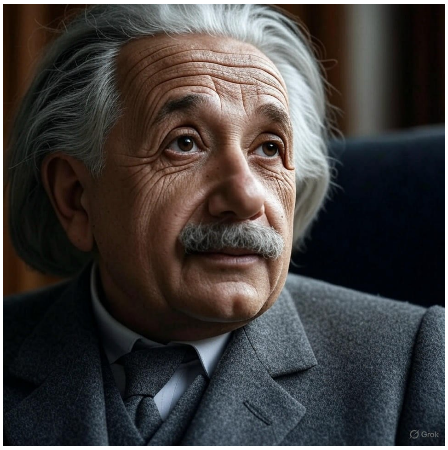
Galileo observed that objects fall at a consistent rate of acceleration, regardless of their masses. Issac Newton formulated the universal law of gravitation, Henry Cavendish calculated the value of G, the gravitational constant. The value of acceleration due to earth's gravity g can be calculated using g = GM/r2 derived from F = mg = GMm/r2, by canceling the objects mass.

All objects fall straight down towards the center of the earth at the same rate of acceleration g. The only reason a feather drops slower than a steel ball is due to air resistance it experiences. Test that in a vacuum space or chamber and find out.

In a vacuum condition where there is no air resistance, both a steel ball and a feather would fall at the same time due to earth's gravity pull towards earth center. Trying it without vacuum, feather will take a longer time due to air's resistance.

So, what is Einstein's theory got to do with gravity on top of all that we know based on Newtons laws and his efforts?

Albert Einstein's theory of general relativity provides the description of gravity explaining it as the curvature of spacetime caused by mass and energy. Albert

Einstein, Hendrick Antoon Lorentz and Hermann Minkowski contributed to the relativity and spacetime concepts. Einstein's theory of relativity reshaped physics by linking mass, space energy and time in the universe governed by the speed of light.

Two theories evolved out of relativity, special (1905) and general. (1915) both proposed by Einstein. The special theory focuses on the relationship between space and time, particularly when dealing with constant velocity. It explains concepts like time dilation and length contraction, which occur as objects move at high speeds relative to each other. The core principle is that the speed of light is constant for all observers, regardless of their relative motion.

The general theory expands upon special relativity by incorporating gravity. It describes gravity as a curvature of spacetime caused by the presence of mass and energy. General relativity explains phenomena like gravitational time dilation, the bending of light around massive objects, and the existence of gravitational waves. The key difference are follows. Special relativity does not include gravity, while general relativity is specifically designed to describe and predict gravitational effects. Special relativity assumes a flat, static spacetime, while general relativity describes a curved, dynamic spacetime. Special relativity is limited to inertial frames, where objects move at a constant velocity, while general relativity can handle all types of reference frames, including accelerating ones. Special relativity uses simpler math, while general relativity requires complex tensor calculus to describe curved spacetime.

Let us add a dimension called time to the three dimensions we know, length, width and height. This is the same time we measure in seconds, days, weeks, years, a life span, a century, a light year and so on. So the object of l x w x h exists along with a time passing with it intertwined and not independent. We, too grow old as time passes, our mass, thus the weight changes as time passes. So time has to be an essential dimension of any object of universe that we cannot ignore. You need space and time both inseparably to describe your reality. You must always move forward through time and is not in your control, your spatial movement on earth is, but always remember you are constantly in motion with earth spinning on it's axis, and around the sun and the sun moving in our milky way galaxy.

It is believed the celestial bodies are spinning on their axis and rotating around other massive bodies is due to spin off from the big bang - the beginning of our universe. And our universe is expanding and is believed at a rate faster than the speed of light. We will likely never be able to measure or be able to see or judge that, as we are limited to the speed of light which is a constant in vacuum. It is believed that there are many universes and we call the domain as multiverse. Sounds like sci-fi. Good to know at least while we roam on this planet!

The fourth dimension is the spacetime or just call it time. People have difference in opinion whether to considered as a dimension or not. Nevertheless, if you are stationery and not moving, and remaining in same spatial position, you will still move forward through time at the maximum rate. And moving through spaces requires you to move through time too. As you move through the space quickly, you would move through time slowly (time dilates) and the spatial dimension of yours along the direction of motion will get shorter (length contraction per Lorentz transformation). The time dilation is proven true by atomic clock corrections in the communication satellite in geostationary orbits velocity relative to a stationery point on earth to be able to precisely pin-point a location on earth!

So, matter contained in an object is now represented as l x w x h x **st**. You guessed it right **st** is spacetime. Space and time are relative and can be affected by an observer's speed and location. Einsteins theory states that time is relative and depends on the observers frame of reference. This means if you are moving at a high speed in a capsule, and from your perspective, time will pass normally like 1 second on a click of 1 second on time clock and your surroundings of capsule will be normal. But to a stationary observer, in his frame of reference l x w x h x st, he will observe your time as passing slowly than his. So he observes that your time is passing by 1 second on his two clicks of 2 seconds for an example, and depending on the speed you are travelling. Then it makes sense to say, life is short, at some point in time, no?

So then, where does that attractive pull come from between the masses? What generates that pull or force by earth called as earth’s gravity? What is the curvature of spacetime that is caused by mass and energy? To understand, we have to continue including the time dimension along with the spatial dimension to understand the gravity effect. My explanation would be only as good as my understanding of the working of spacetime!

Let us understand light. Speed of light is a universal constant. In vacuum. Yes, it does slow down for example in a glass prism and goes back to it's speed upon exiting the prism. Light is made up of photons, which does not have mass but has energy and momentum. A photon is generated from atomic action when electrons transitions from higher energy level to lower, releasing photons spontaneously. The same photon can excite and atom to move its electrons to a higher level. Examples are light bulb, sun, even fluorescent materials. Each photon carries a specific amount of energy, for example higher frequency light like X rays, has more energetic photons, while lower frequency light like radio waves has less energetic photons. The entire electromagnetic spectrum including light is made up of photons. Photons also exhibit wave like behavior. The speed of light does not depend on the speed of the source. Note that the passage of time can be affected by gravity. This means that light might appear to slow down when viewed from a distant location or when it passes through a strong gravitational field.

Spacetime is a 4 dimensional space or interwoven fabric of space. Mass and energy warp this fabric, creating curves and dents in spacetime. These curves or dents are what we experience as gravity. All objects in space are in motion, as a result of the big bang, So they have mass and energy. Larger objects with greater mass causes a larger warp or dent in spacetime. There is always a larger massed body that influences the spacetime more significantly than the smaller ones. The smaller ones move in a curved path as a result of a larger object's warped spacetime. Earth is under the influence of the sun's spacetime. The suns massive gravitational field warps space time. And causing earth to orbit around the sun, in a curved path and this curved path, according to Einstein's general theory of relativity is what we perceive as gravity.

We discussed earlier how the time passes on a speeding object as observed by a stationary observer. Objects naturally move toward regions where time passes more slowly. This is because, in spacetime, the path of least resistance (a geodesic) favors areas with greater time dilation. Gravity is described by general relativity, where massive objects warp spacetime. Objects move along the curves of spacetime, which are called geodesics. These geodesics are not directly caused by time dilation but rather by the curvature of spacetime due to gravity. The time entity or the dimension is curved!! How could one digest this, curved time?