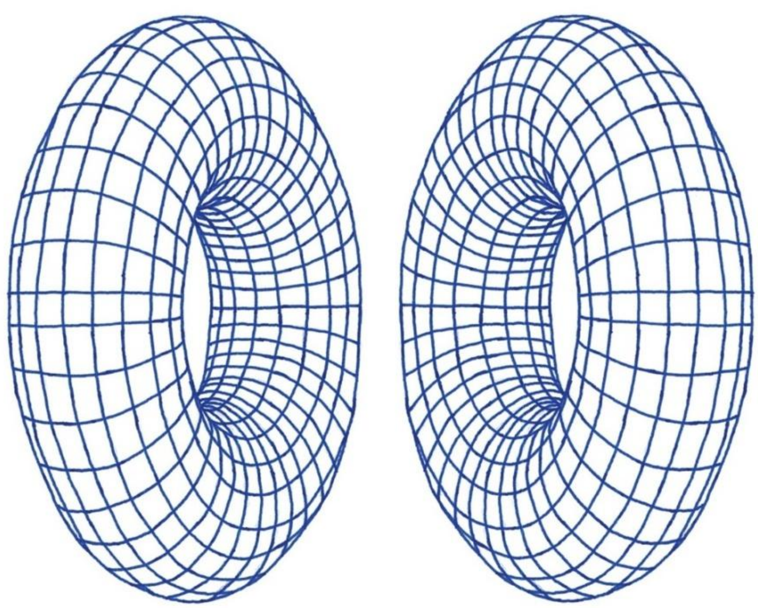
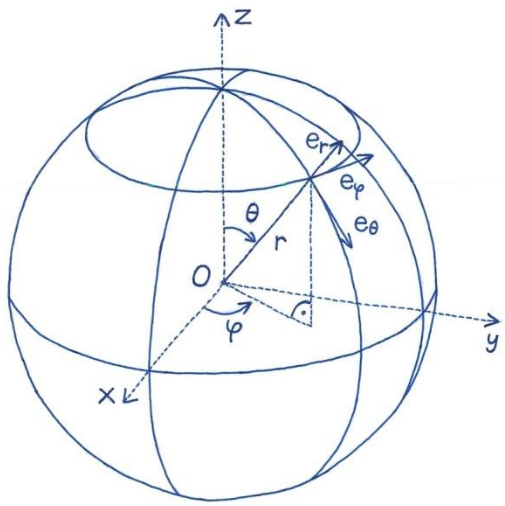
Marek-Lars Kruusen's

technology and science

The physics and mathematics of wormholes. The mini-standard model of particle physics





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General introduction

For a long time, there has been a widely accepted understanding in the world of science that it is possible to travel in time using tunnels in spacetime, also known as wormholes. Similarly, wormholes also assist in performing space travel, since travelling through tunnels in spacetime brings extreme distances in space much closer to us. A tunnel in spacetime, the popular name of which is wormhole, is a curvature of time and space connecting two points in spacetime, which enables to move from one moment in time to another or to move from one point in space to another in an instant or only just in 0 seconds.

A wormhole is a physical object that connects different points in spacetime and is based on a special solution to Einstein's field equations. A wormhole can be visualized as a tunnel with two ends in different points of spacetime (i.e., different locations or different points in time or both).

The actual existence of wormholes has been discussed widely in theoretical physic, which is caused primarily by the existence of different ways of interpreting physics theories concerning time and space.

A wormhole bends spacetime in such a way that it is possible to use a shortcut through another dimension. Therefore, wormholes have in various physical models often been shown rather as two-dimensional, which looks like a ring. However, a three-dimensional ring looks spherical and therefore, in practice, a wormhole looks exactly like a sphere. This means that a wormhole is actually a spherical hole or a hole in spacetime. A hole in spacetime can be interpreted as a tunnel in spacetime (or wormhole). This means that a hole in spacetime and a tunnel in spacetime actually constitute the same physical object.

In the following, general relativity is presented differently from how Albert Einstein did it. This means that the differential equation of gravitational field is derived in such a way as to reduce the possibilities of using tensors. Therefore, it can be said that it is a simplified version of general relativity. It seems to the author that today the theory of general relativity is presented too complicatedly, containing too many elements that are not necessary in reality. For example, Einstein's equation has at least 160 differential solutions, and delving into all these solutions would make understanding the theory and its necessary analysis too complicated. Simplification of physical theories to some extent should be a widespread method in modern physics.

However, simplification does not mean inability to understand complex equations or mathematical analyses. This primarily means eliminating the unnecessary and highlighting the most important relationships. The purpose of this work is to emphasize the physical nature of general relativity and its principles, not so much its mathematical depth as Albert Einstein did. It seems to the author of this paper that many scientists around the world sometimes confuse the fields of mathematics and physics. They are closely related, but physicists primarily describe physical reality, while mathematicians describe the world of numbers. Such a dilemma comes up well, for example, when we want to understand the interior of black holes.

By now it is pretty clear that gravitons mediating the gravitational force cannot exist because gravitational field is not an energy field. For example, an electromagnetic field is an energy field, and therefore such a field is mediated by particles called photons. The mathematical apparatus of quantum mechanics cannot be applied to gravitational field, since the force of gravity is due to the curvature of spacetime, not the properties of the energy field. Therefore, we can count two types of fields that can exist in the universe: energy fields (electromagnetic fields, weak and strong force fields) and fields caused by the curvature of spacetime (gravitational fields).

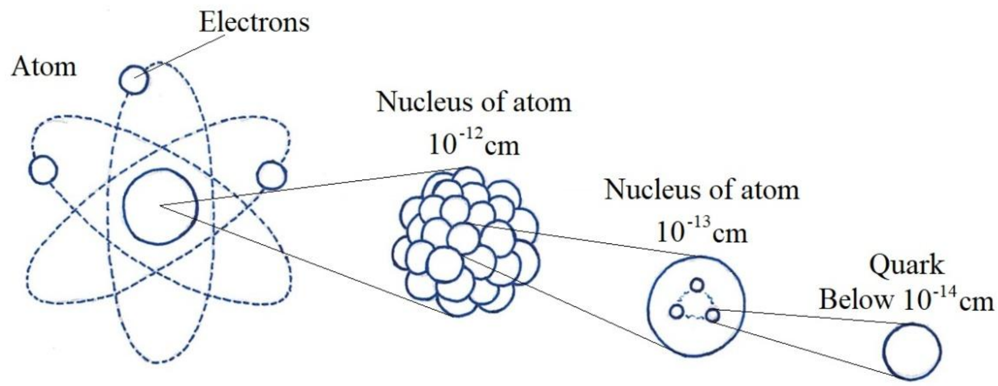
In the field of various theories addressing quantum gravity, a way of thinking of scientists is revealed, which contains erroneous views or the thinking of the age of Newton. Today it is very clear that quantization, which has been successfully done in case of, say, an electromagnetic field, cannot be done in case of a gravitational field. It was once speculated that gravitational waves might indicate or be somehow related to the existence of gravitons, but this kind of thinking used in quantum physics cannot be applied to such a case. Waves and particles are connected, but not in case of gravitational waves. A gravitational wave is not due to a particle's indeterminacy between position and momentum, but is due to the propagation of spacetime curvature perturbation in spacetime. Gravitational waves do not have the possibility of using the concept of mass. Despite all this, the presence of a gravitational field can be studied at the quantum level. It just doesn't manifest as gravitons, it manifests differently.

The topic of gravitational waves is overemphasized in fundamental physics, because it does not give us important information about the nature of quantum gravity and does not connect relativity theory and quantum mechanics. Nowadays and also in the future, we try to focus on the part that goes beyond or borders on the general theory of relativity. It is important to study the part in which the equations of general relativity lose their validity. There are three most important questions in general relativity that a physical theory of time travel can solve: how gravity works at the quantum level, why mass bends spacetime, and what happens in the region of spacetime where the equations lose their validity. The author of the physics theory of time travel is convinced that these questions are in principle solved (3).

Another major area presented in this work is the mini-standard model of elementary particles. Wormholes and the Mini Standard Model of Elementary Particles are part of the physics theory of time travel (3). The "*Standard Model of Elementary Particle Physics*" attempts to describe the properties of all elementary particles that exist in the universe. There are actually many more different particles than can be found in ordinary matter, but mostly these particles are unstable, since the majority of all elementary particles decay relatively quickly into the particles we know everyday. The weak interaction causes all heavy particles to decay into lighter particles. For example, a neutron decays into a proton, an electron, and an antineutrino.

> Here it can be noted that the neutron and the particles of its decay products do not exist simultaneously. Nevertheless, the interaction between the neutron and the decay products can cause the neutron to decay. This follows from the general field theory, which tells us that each type of particle corresponds to a field in space. Such a field exists everywhere and always. A field can exist even if the corresponding particles do not yet exist. In this case, the field energy is minimal. The energy of the field increases "gradually", as particles, or quanta of the corresponding field, appear in the field. Any reaction can be understood as a transfer of energy from one field to another.

That is why in the following we mainly describe the masses of protons, neutrons, electrons, quarks and their intermediate particles (gluons and photons), since these particles are mostly permanent in nature and also the most common elements in the universe. Figure:



Consequently, it can be said that it is a "*mini-standard model*", i.e. a "*smaller version*" of the standard model of elementary particle physics, which describes only the most common and permanent particles in the entire universe. Protons, neutrons and electrons are the basic building blocks of all matter in the universe, as the atoms and molecules formed from them form the basis of any material structure in the universe. It can also be said that the "*mini-standard model*" is in turn the basis for this "*large-standard model*", i.e. the "*standard model of elementary particle physics*".(3)

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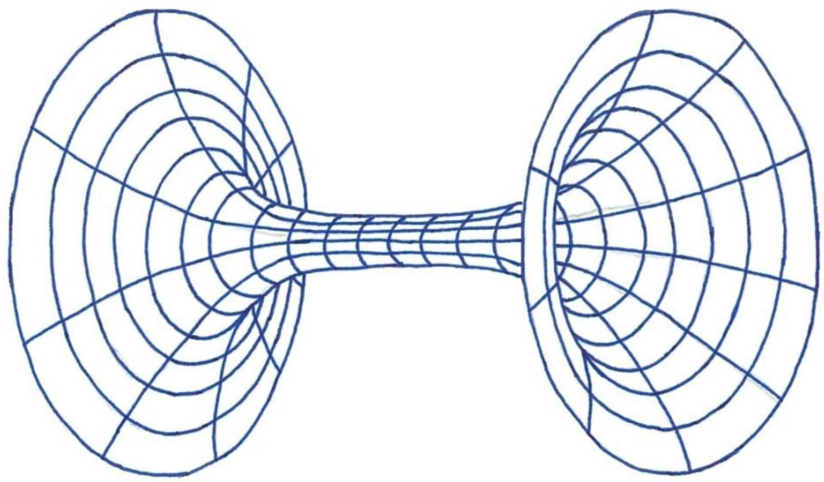
The metrics of a tunnel in spacetime



1 Metric equations of the space-time tunnel

1.1 The metric equation in general relativity

In the following, we show how the Schwarzschild metric is derived using the tensors of general relativity. That is, the Schwarzschild metric is derived in general relativity using tensors of curved spacetime and differential equations for Einstein's gravitational field, which is a common and quite traditional way in general relativity.

For example, the spacetime interval equation derived in special relativity can be presented in spherical coordinates:

$$ds^2 = dt^2 - dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

In this case, it is a line element of the Minkowski world. However, instead of this equation, the following expression is used instead:

$$ds^2 = V^2dt^2 - F^2dr^2 - \varrho^2(d\theta^2 + sin^2\theta d\varphi^2)$$

where multipliers V^2, F^2 ja ϱ^2 can be seen. These multipliers are positive functions of the coordinate r, which must be found from Einstein's law of gravitation:

$$R^{ik} - \frac{1}{2}g^{ik}R = \varkappa T^{ik}$$

It must be a gravitational field that contains nothing else: $T^{ik} = 0$ and at infinity the multipliers must cancel out of the equation. Therefore, we can write:

$$R^{ik} = G^{ik} = 0$$

and

$$R = 0$$

This means that R^{ik} must be expressed through the multipliers V^2, F^2, ϱ^2 and their derivatives, and the resulting expressions must be equalized to zero. Only 2 equations are obtained which are independent of each other. Only one choice remains free, and therefore we can write: $\varrho^2 = r^2$. The multipliers V^2 and F^2 remain unknown. Next, we find these unknowns. To do this, we express the coordinates of the principal tensor, which would be:

$$g_{00} = V^2$$

$$g_{rr} = -F^2 \qquad g^{rr} = -\frac{1}{F^2}$$

$$g_{\theta\theta} = -r^2 \qquad g^{\theta\theta} = -\frac{1}{r^2}$$

$$g_{\varphi\varphi} = -r^2 sin^2\theta \qquad g^{\varphi\varphi} = -\frac{1}{r^2 sin^2\theta}$$

$$g^{00} = \frac{1}{V^2}$$

In the following, it is necessary to use Christoffel's symbol of the second type known in general relativity, i.e. the coefficient of pseudo-parallelism, i.e. the coefficient of affine coherence:

$$\Gamma_{ik}^{l} = \frac{1}{2} g^{lj} \left(\frac{\partial g_{jk}}{\partial x^i} + \frac{\partial g_{ji}}{\partial y^k} - \frac{\partial g_{ik}}{\partial z^j} \right)$$

This equation is the basis for differentiation operations in R_n-space. It can be seen from the equation that Γ_{ik}^{l} is manifested through the coordinates g_{ik} of the basic tensor, due to which the source E_v space is no longer important. Based on Christoffel's symbol of the second type, we can write:

$$\Gamma_{00}^{r} = \frac{V}{F^2} V' \qquad \Gamma_{0r}^{0} = \frac{V'}{V}$$

$$\Gamma_{rr}^{r} = \frac{F'}{F} \qquad \Gamma_{\theta r}^{\theta} = \frac{1}{r}$$

$$\Gamma_{\theta\theta}^{r} = -\frac{1}{F^2} r \qquad \Gamma_{\varphi r}^{\varphi} = \frac{1}{r}$$

$$\Gamma_{\varphi\varphi}^{r} = -\frac{1}{F^2} r sin^2\theta \qquad \Gamma_{\varphi\varphi}^{\theta} = -sin\theta cos\theta$$

$$\Gamma_{\theta\varphi}^{\varphi} = ctg\theta$$

All others: $\Gamma_{kl}^{i} = 0$. It should be mentioned that (') means the derivative with respect to r. In the following, we assume that the following equation holds:

$$F^2 = \frac{1}{V^2}$$

It shows that only one unknown remains: V^2. We will find it in case of $R = 0$. We can designate as follows:

$$V^2 = 1 + u$$

or

$$u = V^2 - 1$$

Here we also use a quantity known in general relativity, called the curvature tensor or the Riemann-Christoffel tensor:

$$R^i_{klm} = \frac{\partial \Gamma^i_{km}}{\partial x^l} - \frac{\partial \Gamma^i_{kl}}{\partial x^m} + \Gamma^i_{sl}\Gamma^s_{km} - \Gamma^i_{sm}\Gamma^s_{kl}$$

Such a tensor characterizes the curvature at point A of R_n-space. Euclidean (pseudo-Euclidean) space is characterized by the fact that zero is at all points in space in case of arbitrary coordinates. This means that if $R^i_{klm} = 0$, then the space is Euclidean. In the Cartesian coordinate system, $R^i_{klm} = 0$, since all derivatives of g_{ik} with respect to coordinates are zero. Using the curvature tensor and then changing the positions of the indices slightly, we can write:

$$R^{0r}{}_{0r} = \frac{u''}{2}$$

$$R^{0\theta}{}_{0\theta} = R^{0\varphi}{}_{0\varphi} = R^{r\theta}{}_{r\theta} = R^{r\varphi}{}_{r\varphi} = \frac{u'}{2r}$$

$$R^{\theta\varphi}{}_{\theta\varphi} = \frac{u}{r^2}$$

All others: $R^{ik}{}_{lm} = 0$. From these equations, the following is obtained:

$$R^0_0 = R^r_r = \frac{u''}{2} + \frac{u'}{r}$$

$$R^\theta_\theta = R^\varphi_\varphi = \frac{u'}{r} + \frac{u}{r^2}$$

$$R = u'' + \frac{4u'}{r} + \frac{2u}{r^2}$$

Thus, according to the above analysis, the following equation must hold:

$$u'' + \frac{4u'}{r} + \frac{2u}{r^2} = 0$$

The general solution of this differential equation is:

$$u = \frac{C_1}{r} + \frac{C_2}{r^2}$$

and

$$V^2 = 1 + \frac{C_1}{r} + \frac{C_2}{r^2}$$

C_1 and C_2 are arbitrary constants. However, the following relationships are found in this general solution:

$$R_0^0 = R_r^r = \frac{C_2}{r^4}$$

$$R_\theta^\theta = R_\varphi^\varphi = -\frac{C_2}{r^4}$$

Finally we see that the obtained equation:

$$V^2 = 1 + \frac{C_1}{r}$$

satisfies the pure gravitational field equations. Analysis shows that this is also the only solution. At this point we can consider the length contraction formula:

$$ds^2 = \left(1 - \frac{\alpha}{r}\right) dt^2$$

which means that the unknown multiplier V^2 contains the Schwarzschild radius α:

$$C_1 = -\alpha$$

According to this, we obtain the Schwarzschild metric in a recognizable form:

$$ds^2 = \left(1 - \frac{\alpha}{r}\right) dt^2 - \frac{1}{1 - \frac{\alpha}{r}} dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

in which we can see the Schwarzschild radius R:

$$\alpha = \frac{2Gm}{c^2} = R$$

However, if we substitute:

$$r \to r + \frac{\alpha}{2}$$

we will get the basic form of the static centrally symmetric gravitational field according to Fok in harmonic coordinates:

$$ds^2 = \frac{r - \frac{\alpha}{2}}{r + \frac{\alpha}{2}} dt^2 - \frac{r + \frac{\alpha}{2}}{r - \frac{\alpha}{2}} dr^2 - \left(r + \frac{\alpha}{2}\right)^2 (d\theta^2 + sin^2\theta d\varphi^2)$$

The distance between two points of a gravitational field is given by the following equation:

$$s = \int_{r_1}^{r_2} F dr = \int_{r_1}^{r_2} \frac{dr}{\sqrt{1 - \frac{\alpha}{r}}}$$

It describes the physical distance between two points A and B located within a radius drawn from the center O.

Previously, we saw how the Schwarzschild metric is derived in general relativity. This is done using various tensors and differential equations that describe the curvature of spacetime or Einstein's gravitational field. However, in the following we will show that it is possible to derive the Schwarzschild metric without using complex tensors. This means that we get exactly the same result even if tensor mathematics is not used. This means a much easier path to the exact same solution.

1.2 Definition of Schwarzschild surface

Newtonian gravitational interaction is manifested between the masses:

$$F = \frac{GMm}{r^2}$$

due to which the bodies have a gravitational potential energy U:

$$U = -\int_r^\infty \vec{F} d\vec{r} = -\frac{GMm}{r}$$

We will analyze the latter integration technique in more detail below. For example, in classical mechanics, work A is defined as the product of force F and displacement s:

$$A = Fs$$

From the latter relation, we take the integral of displacement s:

$$U(R) = \int_\infty^R -F ds, \qquad s = R$$

Since in this case the work A = U(R) is done by the gravitational force F

$$\vec{F} = -G\frac{Mm}{R^2}\vec{R}$$

then we can take the integral of the distance or radius R from the center of the gravitational field:

$$U(R) = -\int_\infty^R -G\frac{Mm}{R'^2}dR'$$

In the integral equation, we move all constants to one side

$$U(R) = GMm \int_{\infty}^{R} \frac{1}{R'^2} dR'$$

and knowing one basic rule of integral calculus

$$\int R'^{-2} = -\frac{1}{R} + C$$

we can finally find an expression for the gravitational potential U. Since dividing a number by infinity results in zero

$$U(R) = +\frac{GMm}{\infty} - \frac{GMm}{R}$$

we obtain the equation for gravitational potential U:

$$U(R) = -\frac{GMm}{R}$$

The zero point is at infinity ∞ . The gravitational field itself has no energy, i.e. the gravitational field is not an energy field like an electric field is, for example. However, a physical body possesses potential energy while in a gravitational field. That's what this gravitational potential equation means.

In order for a physical body to permanently leave the sphere of influence of the gravitational force F on the surface of a black hole, the kinetic energy E of the body must be equal to work A:

$$\frac{mv^2}{2} = A$$

where A is the work of the gravitational force $F_g = G\frac{Mm}{R^2}$ during the movement of the body from the surface of the black hole, or R, to infinity:

$$A = \int_{s_1}^{s_2} \vec{F}_s \, d\vec{s} = \int_{R_1}^{R_2} \vec{F}_R d\vec{r}, \qquad where\ R_2 = \infty$$

The kinetic energy E is proportional to the work done:

$$Fs = ma = mg = m\frac{dv}{dt}\frac{ds}{ds} = mv\frac{dv}{ds}$$

or

$$Fs = mv\frac{dv}{ds}$$

It can be seen from the latter relation that by differentiating the expression of work A, we get the equation for kinetic energy as follows:

$$dA = Fsds = mvdv = d\left(\frac{1}{2}mv^2\right)$$

When we integrate the latter expression:

$$A = \int_{s_1}^{s_2} \vec{F} s d\vec{s}$$

we obtain the mathematical expression for kinetic energy:

$$A = \int dA = \int_0^{\frac{mv^2}{2}} d\left(\frac{1}{2}mv^2\right) = \frac{1}{2}mv^2 = \frac{mv^2}{2}$$

Since gravitational potential is equal to work A:

$$A = G\frac{Mm}{R}$$

then the dependence of the body's movement speed v on the radius of gravity R can be obtained as follows:

$$\frac{mv^2}{2} = G\frac{Mm}{R}$$

$$R = \frac{2GM}{v^2}$$

The escape velocity of a black hole, or the second cosmic velocity v

$$v = \sqrt{\frac{2GM}{R}}$$

is equal to the speed of light c on the surface of the black hole, i.e. at a distance R from the center:

$$R = \frac{2GM}{c^2}$$

The speed of light c is the highest possible speed in the whole universe:

$$c = \frac{l}{t}$$

and this is true if viewed from any reference system:

$$c = \frac{d}{t`} = \frac{\sqrt{l^2 + v^2 t`^2}}{t`} = c$$

If we transform the latter expression mathematically in the following way:

$$(ct)^2 + (vt`)^2 = c^2 t`^2$$

or

$$(ct)^2 = (c^2 - v^2) t`^2$$

then we will see that when moving at the speed of light c:

$$t^2 = \frac{c^2 - v^2}{c^2} t`^2 = \left[1 - \left(\frac{v}{c}\right)^2\right] t`^2$$

time t' would "transform" or "slow down" to infinity:

$$t` = \frac{t}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{t}{\sqrt{1 - \frac{c^2}{c^2}}} = \infty$$

Assuming that a spacecraft starts its journey from Earth with a constant speed v toward a star located at a distance l, an observer who remained on Earth measures the duration of the journey as t:

$$t = \frac{l}{v}$$

However, the clock on board the ship, moving at a velocity v, shows less time:

$$t' = \frac{t}{y}$$

Therefore, the journey duration is shortened for the travelers:

$$l' = t'v = \frac{t}{y} v = \frac{l}{y} = l\sqrt{1 - \frac{v^2}{c^2}}$$

The initial and final points of the journey move at the speed of v. This is how the journey appears to the passengers on board, not to the person remaining on Earth. This contraction occurs for any purposeful motion. For example, if a one-meter ruler moves at a speed of 0.8c (or 240 000 km/s), it is only 60 cm long. However, in the co-moving system, this ruler still measures 1 meter. The dimensions of objects in other directions, however, do not change. For instance, if a sphere moves at an extremely high speed, it becomes a compressed spheroid in the direction of motion. The Lorentz contraction factor approaches infinity as the velocity approaches the speed of light in a vacuum, causing the length of the object to approach zero.

In Albert Einstein's general theory of relativity, in the square root expression in the equation for time dilation

$$\sqrt{1-\frac{v^2}{c^2}}=\frac{t}{t'}$$

v^2 is replaced with the second cosmic velocity known from Newton's theory of gravitation

$$v=\sqrt{\frac{2GM}{r}}$$

or

$$v^2=\frac{2GM}{r}$$

$\frac{GM}{r}$ is the gravitational potential and $\frac{v^2}{2}$ is the kinetic energy of a moving body:

$$\frac{v^2}{2}=\frac{GM}{r}$$

Consequently, the following mathematical transformations are obtained:

$$\sqrt{1-\frac{v^2}{c^2}}=\sqrt{1-\frac{2GM}{rc^2}}=\sqrt{1-\frac{R}{r}}$$

where

$$\frac{2GM}{c^2}=R$$

is the expression for the Schwarzschild radius and r is the distance from the center of the planet. The second cosmic speed is the speed of a body that allows it to permanently leave the sphere of influence of some kind of planet. It is also called the escape velocity and, for example, on the surface of a black hole, or the Schwarzschild surface of the curvature of spacetime, it is equal to the speed of light c. Schwarzschild radius R

$$R=\frac{2GM}{c^2}$$

forms a centrally symmetric surface S

$$S=4\pi R^2$$

on the “surface” of which time, for example,

$$t' = \frac{t}{\sqrt{1 - \frac{R}{r}}}$$

has transformed of curved to infinity:

$$t' = \frac{t}{\sqrt{1 - 1}} = \infty$$

since R = r. Therefore, the multiplier y has an infinitely large value:

$$\frac{t'}{t} = \frac{1}{\sqrt{1 - \frac{R}{r}}} = y = \infty$$

This surface is called the "trapped surface in spacetime".

1.3 Metric equation of gravitational field

From the time and space transformation equations, it is possible to mathematically derive the metric equation for the spacetime interval, which describes the distance ds between two points in four-dimensional spacetime. To do this, we start by making the following mathematical transformations in the time dilation equation:

$$t' = \frac{t}{\sqrt{1 - \frac{v^2}{c^2}}}$$

or

$$t = \tau = t' \sqrt{1 - \frac{v^2}{c^2}}$$

or

$$\tau = \sqrt{1 - \frac{v^2}{c^2}} \Delta t$$

where

$$t' = \Delta t = t_2 - t_1$$

Let's square both sides of the latter resulting equation

$$\tau^2 = \left(1 - \frac{v^2}{c^2}\right)\Delta t^2$$

We know from elementary mathematics that the distance between two points in three-dimensional space is given by the Pythagorean theorem:

$$l^2 = \Delta x^2 + \Delta y^2 + \Delta z^2$$

in which the members mean the following:

$$\Delta x = x_2 - x_1$$

$$\Delta y = y_2 - y_1$$

$$\Delta z = z_2 - z_1$$

However, the definition of velocity v from classical mechanics is as follows:

$$v = \frac{l}{\Delta t}$$

Let's square both sides of the latter equation and take into account the previous relationships as well:

$$v^2 = \frac{l^2}{\Delta t^2} = \frac{\Delta x^2 + \Delta y^2 + \Delta z^2}{\Delta t^2}$$

We transfer the latter equation to the time dilation equation and get the following result as:

$$\tau^2 = \left(1 - \frac{\Delta x^2 + \Delta y^2 + \Delta z^2}{\Delta t^2 c^2}\right)\Delta t^2 = \Delta t^2 - \frac{\Delta x^2 + \Delta y^2 + \Delta z^2}{c^2}$$

Let's multiply both sides of the resulting equation by c^2 and we get:

$$c^2\tau^2 = c^2\Delta t^2 - \Delta x^2 - \Delta y^2 - \Delta z^2$$

where

$$c\tau = s$$

or

$$c = \frac{s}{\tau}$$

Finally, we obtain the final equation we were looking for

$$s^2 = c^2\Delta t^2 - \Delta x^2 - \Delta y^2 - \Delta z^2$$

or

$$s = \sqrt{c^2\Delta t^2 - l^2}$$

which indicates the interval between events A and B. Since τ does not depend on an inertial system, the interval between the two observed events A and B is the same in all inertial systems. The interval s is an invariant, but the time interval and the segment length are not invariants. In case of light, the interval is: τ = 0 and thus:

$$0 = c^2 \Delta t^2 - l^2$$

A quantity that remains unchanged or constant during a transformation is called an invariant in physics (for example, an invariant is the length of a vector during coordinate rotation). Likewise, the distance ds between two spatial points is invariant with respect to Galilean transformations:

$$\sum_{i=1}^{4} {x_i}^2 = const$$

or

$$x_i x_i = const$$

However, the absolute value of velocity is not invariant (except in case of rotations of space). The speed of light c is invariant under Lorentz transformations and therefore its spacetime interval is equal to zero:

$$x_i x_i - c^2 t^2 = 0 = invariant$$

or

$$s = \sqrt{\Delta x_i \Delta x_i - c^2 \Delta t^2} = invariant$$

All relativistic dynamics is invariant to spacetime rotations. This is also the spacetime interval, i.e. the distance between two points s in spacetime:

$$s^2 = \Delta x_\mu \Delta x_\mu = \sum_{n=1}^{4} {\Delta x_\mu}^2 = \Delta l^2 - c^2 \Delta t^2$$

where $\mu = 1{,}2{,}3{,}4,$ $\Delta l^2 = \Delta x_j \Delta x_j$ and $\Delta x_4 = ic\Delta t.$ The equation for the latter interval can be expressed as follows as well:

$$ds = \sqrt{dl^2 - c^2 dt^2}$$

from which it is possible to derive, for example, the time dilation equation:

$$ds = -cdt\sqrt{1 - \frac{v^2}{c^2}} = -cdt\sqrt{1 - \frac{1}{c^2}\frac{dl^2}{dt^2}}$$

The distance between two points in four-dimensional spacetime is described by a spacetime interval:

$$ds^2 = c^2 dt^2 - dx^2 - dy^2 - dz^2$$

or

$$c^2 d\tau^2 = c^2 dt^2 - dx^2 - dy^2 - dz^2$$

In the following, we proceed from the spacetime interval to describe the distance between two points in a curved spacetime, i.e. in a centrally symmetric gravitational field.

In the following, we derive a metric equation without using tensor mathematics, which mathematically describes the gravitational field, i.e. the centrally symmetric curvature of spacetime, which does not change over time. For example, the spacetime interval equation derived in special relativity

$$s^2 = c^2 \Delta t^2 - \Delta x^2 - \Delta y^2 - \Delta z^2$$

or

$$s = \sqrt{c^2 \Delta t^2 - l^2}$$

indicates the interval between events A and B. Derived equation for spacetime interval metric:

$$ds^2 = c^2 \tau^2 = c^2 dt^2 - (dx^2 + dy^2 + dz^2) = c^2 dt^2 - dl^2$$

has a temporal part

$${ds_1}^2 = c^2 dt^2$$

and a spatial part

$$-{ds_2}^2 = -(dx^2 + dy^2 + dz^2) = -dl^2$$

This means that by adding these two parts, we get the metric equation for the spacetime interval:

$${ds_1}^2 + \left(-{ds_2}^2\right) = {ds_1}^2 - {ds_2}^2 = ds^2$$

or

$${ds_1}^2 - {ds_2}^2 = c^2 dt^2 - dl^2 = c^2 dt^2 - dx^2 - dy^2 - dz^2 = ds^2$$

The spacetime interval ds is the product of the speed of light c and the "own time" τ:

$$ds^2 = c^2 \tau^2$$

where $\tau^2 \neq dt^2$. The closer to the center of the gravitational field, the more time changes relative to the external observer, i.e. gravitational time dilation occurs:

$$dt = \frac{d\tau}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{d\tau}{\sqrt{1 - \frac{2GM}{c^2 r}}} = \frac{d\tau}{\sqrt{1 - \frac{\alpha}{r}}}$$

or

$$d\tau = \sqrt{1 - \frac{\alpha}{r}}\, dt$$

and therefore we can express the spacetime interval as follows (with time dilation):

$$c^2 d\tau^2 = \left(1 - \frac{\alpha}{r}\right) dt^2 - dx^2 - dy^2 - dz^2$$

However, besides the temporal part, there is also a spatial part in the spacetime interval equation:

$$ds^2 = c^2 d\tau^2 = dx^2 - dy^2 - dz^2$$

Since the gravitational field is mostly centrosymmetric, we express its spatial part in spherical coordinates:

$$ds^2 = dr^2 - r^2 d\theta^2 + r^2 sin^2\theta \, d\varphi^2 = dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

In this equation, we only consider the change in radius:

$$ds^2 = dr^2$$

or

$$c^2 d\tau^2 = dr^2$$

since the distance, or length, between two points in space changes only when moving towards the center of the gravitational field, and not perpendicular to the radius of the field:

$$l' = l\sqrt{1 - \frac{\alpha}{r}}$$

or

$$dr = c d\tau \sqrt{1 - \frac{\alpha}{r}}$$

However, taking the square of the latter expression

$$dr^2 = c^2 d\tau^2 \left(1 - \frac{\alpha}{r}\right)$$

we obtain the expression for the length transformation only in the direction of the center of the field

$$c^2 d\tau^2 = \frac{dr^2}{\left(1 - \frac{\alpha}{r}\right)}$$

We can therefore express the spatial part of the spacetime interval equation as follows:

$$ds^2 = c^2 d\tau^2 = \frac{dr^2}{\left(1 - \frac{\alpha}{r}\right)} - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

If we consider the temporal and spatial parts simultaneously, i.e. add these two parts together, we obtain a metric equation that mathematically describes a pure gravitational field, i.e. the centrally symmetric curvature of spacetime:

$$ds^2 = \left(1 - \frac{\alpha}{r}\right) dt^2 - \frac{1}{\left(1 - \frac{\alpha}{r}\right)} dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

where

$$\alpha = \frac{2Gm}{c^2}$$

is called the Schwarzschild radius, which indicates the size of the hole in spacetime that exists at the center of the field.

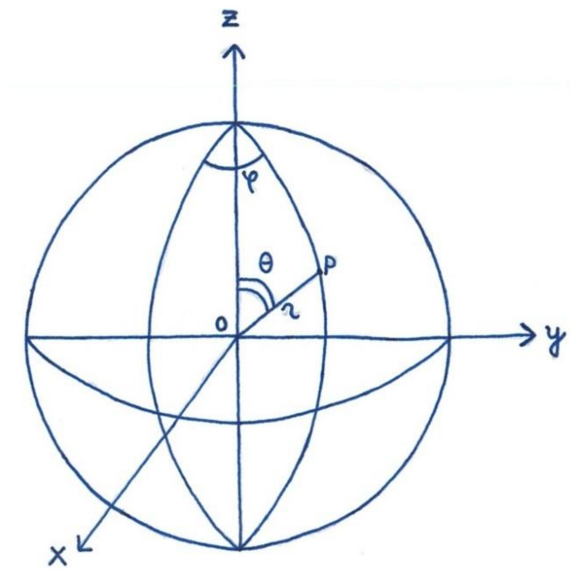


Figure: Spherical coordinates.

In 1916, a scientist named Schwarzschild found such a solution, and therefore it is also called the Schwarzschild metric. However, if we replace α and r^2 in the latter equation with

$$r + \frac{R}{2}$$

and do some mathematical transformations, however, we get the following metric form:

$$ds^2 = \frac{r - \frac{R}{2}}{r + \frac{R}{2}} dt^2 - \frac{r + \frac{R}{2}}{r - \frac{R}{2}} dr^2 - \left(r + \frac{R}{2}\right)^2 (d\theta^2 + sin^2\theta d\varphi^2)$$

The resulting expression is considered the basic form of the Fok gravitational field. This equation describes a field that does not change in time and is centrally symmetric. Such a form is presented in harmonic coordinates. R is the Schwarzschild radius.

Shortening of length is meant as the physical distance between two spatial points A and B (for example, the distance between two points of the gravitational field). These points are located on a radius drawn from the center 0:

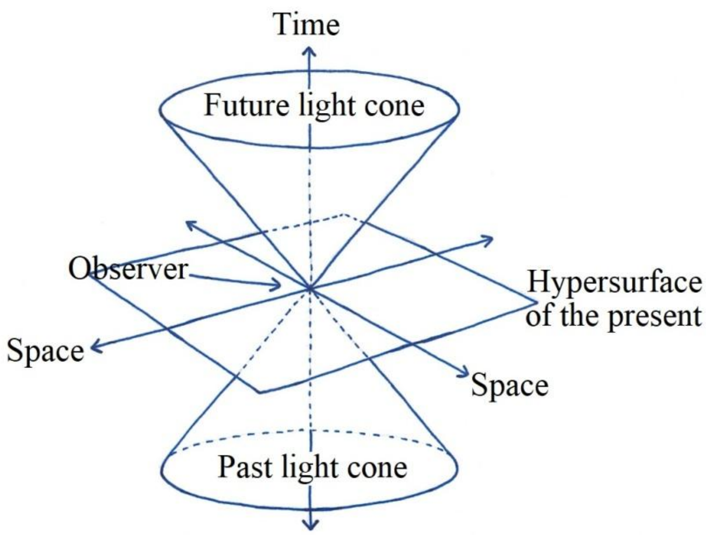
$$s = \int_{r_1}^{r_2} F dr = \int_{r_1}^{r_2} \frac{dr}{\sqrt{1 - \frac{R}{r}}}$$

If you move away from the center of the field, the distance between two spatial points of the field increases.

1.4 Light cone and Minkowski spacetime

The spacetime interval equation presented in relativity shows the distance between two points in spacetime. However, it can also show the causality of events, or causal relationships. We will show this below through a light cone, which can also be described in the theory of relativity. For example, if it is a Minkowski spacetime, the light cone is described by lines at an angle of 45^0 in the ct-r coordinate system.

The causality of events, or causality-related relationship, is described by the light cone. If it is a Minkowski spacetime, the light cone is described by lines at an angle of 45^0 in the ct-r coordinate system. Figure:



For radially incident light, the 4-interval is in Minkowski spacetime:

$$ds^2 = -c^2dt^2 + dr^2 = 0$$

From this, the following equality can be seen:

$$cdt = \pm dr$$

in which the "+" sign describes the light signal leaving a point and the "-" sign the light signal entering the point. The 4-interval of the light signal can be represented in Schwarzschild coordinates as follows:

$$ds^2 = -\left(1 - \frac{R}{r}\right)c^2dt^2 + \left(1 - \frac{R}{r}\right)^{-1} dr^2 = 0$$

from which it can in turn be seen:

$$cdt = \pm \frac{dr}{1 - \frac{R}{r}}$$

We take the integral of the latter expression, the right-hand side of which can be presented as follows:

$$\pm \int \frac{dr}{1 - \frac{R}{r}} = \pm \int \frac{dr}{\frac{r-R}{r}} = \pm \int \frac{rdr}{r-R} = I$$

If in the resulting integral we make an exchange of variables:

$$x = r - R$$

we will get the integral in the following form:

$$I = \int \frac{x+R}{x} dr = \int \left(1 + \frac{R}{x}\right) dx = x + R\ ln|x| + const =$$

$$= r - R + R\ ln|r-R| + const \equiv r + R\ ln|r-R| + const$$

This means that the equation for the interval of the light signal is in the following form:

$$ct = \pm(r + R\ ln|r-R| + const)$$

It follows that time and space are "normal" in region I. Since the geodesic lines or their world lines lie inside the light cone, they are therefore time-like for the particles. However, in region II, time and space are interchanged. The world line is time-like, i.e. the expression:

$$1 - \frac{R}{r}$$

changes sign when t is "fixed". If the world line remains "time-like":

$$ds^2 < 0$$

then the equality must hold: $dr \neq 0$. It follows that the particle moves inside the Schwarzschild surface only in the direction of the point singularity: $r \to 0$.

Since the Planck surface S and the Schwarzschild surface S are physically equivalent (time and space no longer exist on both surfaces), nothing can exist inside the Schwarzschild surface, including mass and point singularity. On the scale of the Planck length l, time and space cease to exist, which physically means that on spatial scales smaller than this, the universe no longer has a physical existence. Since the scale of the Planck length l forms an imaginary Planck surface extending over the entire universe, the physical nature of which overlaps with the Schwarzschild surface at the center of a black hole, it can be concluded that the universe also no longer has a physical existence inside the Schwarzschild surface. Therefore, no black hole mass or point singularity can exist inside it, so the black hole mass must have "formed" on the Schwarzschild surface.

Absolutely nothing can exist in the "region" inside the Schwarzschild surface of a black hole as a hole in spacetime. This also means that no point singularity in the center of a black hole, the existence of which was "theoretically" proved in 1965 by the English scientist Roger Penrose, can actually exist. A point singularity is simply a mathematical point from which the Schwarzschild radius R is measured, which determines the "size" of a black hole as a hole in spacetime, i.e. the size of an imaginary sphere in space, the further away from the surface the infinite curvature of spacetime becomes more and more flat. Therefore, for example, the mass of a black hole cannot exist inside the Schwarzschild surface, but must be "outside" it (i.e. on the Shcwarzschild surface). A non-rotating Schwarzschild surface would be perfectly spherical, but it could also rotate and orbit some other celestial body.

Due to the analysis presented in the theory of time travel, as well as the theory of quantum gravity, the mass of a black hole cannot exist "inside" the Schwarzschild surface, but only "on" it. This means that when a substance falls into a black hole, in addition to the great gravitational force, the falling substance is also affected by the transformations of time and space, i.e. the curvature of spacetime. This is the cause of the gravitational force, but it also causes the three-dimensional shape of the still falling matter to change into a two-dimensional shape, due to which the three-dimensional physical body transforms into a two-dimensional body, i.e. an infinitely narrow/thin body, when it reaches the Schwarzschild surface of a black hole. For example, we can imagine a sheet of paper that is infinitely thin. In this sense, the Schwarzschild surface of a black hole is still a "physical surface".

According to the theory of quantum gravity, the curvature of spacetime occurs according to the Schwarzschild metric (or Einstein's gravitational field tensor equation) UNTIL the Planck length l and AFTER THAT, spacetime is immediately curved to infinity. From the Planck length l on the "smaller scale", the infinite curvature of spacetime, i.e. the cessation of physical existence of spacetime, is immediately manifested. In case of a black hole, this means that a three-dimensional physical body contracts into a "two-dimensional sheet" whose diameter can eventually only correspond to the Planck length l, after which the volume of the body (in this case the diameter of the "sheet") becomes zero "instantly".

1.5 Metric equation with time and space transformations

A metric equation for a spacetime interval is often expressed in terms of x, y, z, and ct differential coordinates. It shows the distance between two points in time and space:

$$ds^2 = c^2dt^2 - dx^2 - dy^2 - dz^2$$

However, such an expression can also include the transformations of time and space known in special relativity, which also takes into account changes in spacetime coordinates when the speed of movement v approaches the speed of light c in vacuum:

$$ds^2 = \left(1 - \frac{v^2}{c^2}\right)c^2dt^2 - \frac{1}{\left(1 - \frac{v^2}{c^2}\right)}dl^2$$

not just coordinates. For example, in general relativity, this is the Schwarzschild metric:

$$ds^2 = \left(1 - \frac{R_M}{r}\right)dt^2 - \frac{1}{1 - \frac{R_M}{r}}dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

in which there are radii instead of velocities. However, it can also be expressed in terms of velocities, which we will show below.

The distance between two points in four-dimensional spacetime is described by a spacetime interval:

$$ds^2 = c^2dt^2 - dx^2 - dy^2 - dz^2$$

or

$$c^2d\tau^2 = c^2dt^2 - dx^2 - dy^2 - dz^2$$

In the following, we proceed from the spacetime interval to describe the distance between two points in transformed spacetime. The metric equation of the derived spacetime interval:

$$ds^2 = c^2\tau^2 = c^2dt^2 - (dx^2 + dy^2 + dz^2) = c^2dt^2 - dl^2$$

has a temporal part

$${ds_1}^2 = c^2dt^2$$

and spatial part

$$-{ds_2}^2 = -(dx^2 + dy^2 + dz^2) = -dl^2$$

This means that by adding these two parts, we get the metric equation for the spacetime interval:

$${ds_1}^2 + \left(-{ds_2}^2\right) = {ds_1}^2 - {ds_2}^2 = ds^2$$

or

$${ds_1}^2 - {ds_2}^2 = c^2dt^2 - dl^2 = c^2dt^2 - dx^2 - dy^2 - dz^2 = ds^2$$

The spacetime interval ds is the product of the speed of light c and the "own time" τ:

$$ds^2 = c^2\tau^2$$

where $\tau^2 \neq dt^2$. The closer to the speed of light c in vacuum, the more time changes relative to an external observer, i.e. time dilation occurs:

$$dt = \frac{d\tau}{\sqrt{1 - \frac{v^2}{c^2}}}$$

or

$$d\tau = \sqrt{1 - \frac{v^2}{c^2}}\, dt$$

and therefore we can express the spacetime interval as follows (with time dilation):

$$c^2 d\tau^2 = c^2 \left(1 - \frac{v^2}{c^2}\right) dt^2 - dx^2 - dy^2 - dz^2$$

However, besides the temporal part, there is also a spatial part in the spacetime interval equation:

$$ds^2 = c^2 d\tau^2 = dx^2 - dy^2 - dz^2 = dl^2$$

In this equation, we only consider the change in body length in the direction of movement:

$$ds^2 = dl^2$$

or

$$c^2 d\tau^2 = dl^2$$

because the distance, or length, between two spatial points changes only in the direction of movement

$$l' = l\sqrt{1 - \frac{v^2}{c^2}}$$

or

$$dl = l\sqrt{1 - \frac{v^2}{c^2}}$$

However, taking the square of the latter expression

$$dl^2 = l^2 \left(1 - \frac{v^2}{c^2}\right)$$

we get the expression for the transformation of length only in the direction of movement

$$l^2 = \frac{dl^2}{\left(1 - \frac{v^2}{c^2}\right)}$$

We can therefore express the spatial part of the spacetime interval equation as follows:

$$ds^2 = c^2 d\tau^2 = \frac{dl^2}{\left(1 - \frac{v^2}{c^2}\right)}$$

If we consider the temporal and spatial parts at the same time, i.e. add these two parts together, we get a metric equation that mathematically describes the transformation of spacetime when the velocity of the body approaches the speed of light c in vacuum:

$$ds^2 = \left(1 - \frac{v^2}{c^2}\right) c^2 dt^2 - \frac{1}{\left(1 - \frac{v^2}{c^2}\right)} dl^2$$

A metric equation for a spacetime interval is often expressed as x, y, z, and ct differential coordinates, indicating the distance between two points in time and space. However, such an expression can also include time and space transformations known in special relativity, which also takes into account changes in spacetime coordinates when the speed of movement v approaches the speed of light c in vacuum, not just coordinates. For example, in general relativity, this is the Schwarzschild metric, with radii instead of velocities. However, it can also be expressed in terms of velocities, which we showed earlier.

1.6 Reissner-Nordström metrics

1.6.1 Introduction

The Reissner-Nordström metric shows us that in addition to mass, spacetime is also curved by the body's electric charge. The greater the electric charge, the more it warps spacetime. This also means that a black hole can also form with a very large electric charge, not just because of a very large mass. The Nordström metric first emerged when describing electrically charged black holes. Electrically charged black holes have two radii: the Schwarzschild radius and the Nordström radius. The Nordström radius occurs only in the case of very large electric charges. The Reissner-Nordström metric is derived from the equations of Albert Einstein's theory of general relativity, but it must be emphasized that such a metric has no theoretical or practical significance. There are two main reasons for this. First, electrically charged black holes do not actually exist, at least they have not been discovered yet. There is a small chance that they will be discovered in the future. Second, an extremely large electric charge is required for the Nordström radius to occur. Such a charge cannot be obtained from anywhere, and they cannot be created by themselves, because in case of large electric charges, electrical repulsions begin to appear, which would prevent the creation of large electric charges. Therefore, the Nordsrtöm metric is an unusable and unnecessary part of theoretical physics and practical technology that can be omitted from modern general relativity courses. Nordsrtöm's metric cannot describe any natural phenomenon that can be empirically observed or verified.

1.6.2 Reissner-Nordström metrics

The effect of electric charge on spacetime is mathematically described by the Nordström metric. However, the mathematical derivation of this metric from the tensor calculations of general relativity is only a mathematical inference of the effect of charge on spacetime. However, the physical conclusion follows from the law of equivalence of mass and energy known from special relativity. This means that one is derived from mathematics, but the other only from physics. As a final conclusion, it can be found that both mathematical and physical derivation of the effect of charge on spacetime completely overlap with each other.

In the following, we show how the Nordström metric is derived using the tensors of general relativity. This means that the Nordström metric is derived in general relativity using curved spacetime tensors and Einstein's gravitational field differential equations, which is a common and quite traditional way in general relativity.

One of the foundations of the general theory of relativity is the differential equations of the gravitational field. In these equations, the following expression is obtained for the definition of the radius used in spherical coordinates:

$$R = -\varkappa m$$

where $\varkappa$ indicates a constant. The mass m is expressed through the basic tensor g_{ik} and the energy tensor T^{ik} as follows:

$$g_{ik}T^{ik} = g_{ik}\left(m_0 \frac{dx^i}{ds}\frac{dx^k}{ds} + F^{ik}\right) = m_0 + g_{ik}F^{ik} = m$$

According to this, we can express the mass m in the radius equation:

$$R = -\varkappa m = -\varkappa\left(m_0 + g_{ik}F^{ik}\right)$$

Since F^{ik} is by definition the energy-momentum tensor $\hat{F}$ of an electromagnetic field:

$$F^{ik} = -\frac{1}{4\pi}\left(\varphi^{is}\varphi_s^k - \frac{1}{4}g^{ik}f\right)$$

$$F^{ik} = F^{ki}$$

then thus it can equal zero: $g_{ik}F^{ik} = 0$. If $R = 0$, then $m_0 = 0$. Through the coordinates of the basic tensor and the curve tensor, i.e. the Riemann-Christoffel tensor, the expressions are obtained:

$$R_0^0 = R_r^r = \frac{C_2}{r^4}$$

$$R_\vartheta^\vartheta = R_\varphi^\varphi = -\frac{C_2}{r^4}$$

According to these and the above relations, the following equations are written:

$$\frac{C_2}{r^4} = \frac{\varkappa}{c^2} F_0^0 = \frac{\varkappa}{c^2} F_r^r = -\frac{\varkappa}{c^2} F_\vartheta^\vartheta = -\frac{\varkappa}{c^2} F_\varphi^\varphi$$

Since F^{ik} could be expressed in energy units, then therefore the right side is divided by c^2. As a result, we can write:

$$F_k^i = -\frac{1}{4\pi}\left(\varphi^{is}\varphi_{ks} - \frac{1}{4} g_k^i f\right)$$

where it appears in return:

$$f = \varphi_{ik}\varphi^{ik} = -\frac{2E^{r^2}}{V^4}$$

The latter expression is obtained from the tensor φ_{ik}, since a scalar can be formed from this tensor:

$$f = \varphi_{ik}\varphi^{ik} = 2(H^2 - E^2)$$

or

$$f = \varphi_{ik}\varphi^{ik} = -2E^2$$

if there is no presence of magnetic field H^2. All electromagnetic field components are related to spatial coordinates:

$$E^2 = E^{x^2} + E^{y^2} + E^{z^2} = E^{r^2}$$

However, in this case, the quotient occurs in the scalar:

$$f = \varphi_{ik}\varphi^{ik} = -\frac{2E^{r^2}}{V^4}$$

The electromagnetic field component $E^r = {\varphi^r}_0$ is the only one that can be non-zero, because the field is centrally symmetric. It also satisfies Maxwell's differential equations, which in general relativity are expressed as follows:

$$\frac{\partial}{\partial x^i}\varphi^{ik} = 4\pi\varrho_0 \frac{dx^k}{d\tau}\left(= 4\pi\varrho\frac{dx^k}{dt}\right)$$

$$\frac{\partial\varphi_{ik}}{\partial x^l} + \frac{\partial\varphi_{kl}}{\partial x^i} + \frac{\partial\varphi_{li}}{\partial x^k} = 0$$

In it, i, k, and l are combinations of the numbers 0, 1, 2, and 3. This gives a total of 8 equations. Consequently, we can write:

$$F_k^i = -\frac{1}{4\pi}\left(\varphi^{is}\varphi_{ks} - \frac{1}{2} g_k^i \frac{2E^{r^2}}{-V^4}\right)$$

and

$$F_0^0 = F_r^r = \frac{E^{r^2}}{8\pi V^4}$$

$$F_\vartheta^\vartheta = F_\varphi^\varphi = -\frac{E^{r^2}}{8\pi V^4}$$

Since we were able to derive the following equations above:

$$\frac{C_2}{r^4} = \frac{\varkappa}{c^2} F_0^0 = \frac{\varkappa}{c^2} F_r^r = -\frac{\varkappa}{c^2} F_\vartheta^\vartheta = -\frac{\varkappa}{c^2} F_\varphi^\varphi$$

then according to these we also get such an equation:

$$\frac{C_2}{r^4} = \frac{\varkappa E^{r^2}}{8\pi c^2 V^4}$$

or

$$C_2 = \frac{\varkappa}{8\pi c^2} \frac{E^{r^2} r^4}{V^4}$$

If we define the electromagnetic field component as:

$$\varphi^r{}_0 = E^r = \frac{qV^2}{r^2}$$

in which q would be the electric charge of the central body, then we would get the following potential expressions:

$$C_2 = \beta^2 = \frac{\varkappa q^2}{8\pi c^2} \qquad \varphi_{r_0} = -\frac{q}{r^2}$$

$$\varphi^{r_0} = \frac{q}{r^2} \qquad A_0 = \frac{q}{r}$$

Such equations give us the square of the line element in general relativity:

$$ds^2 = \left(1 - \frac{\alpha}{r} + \frac{\beta^2}{r^2}\right) dt^2 - \frac{1}{1 - \frac{\alpha}{r} + \frac{\beta^2}{r^2}} dr^2 - r^2(d\vartheta^2 + sin^2\vartheta d\varphi^2)$$

in which the Schwarzschild radius expression occurs:

$$\alpha = \frac{2Gm}{c^2} = R$$

and expression for the Nordström radius:

$$\beta = \sqrt{\frac{q^2 G}{4\pi\varepsilon_0 c^4}} = R$$

Such a metric equation describes the Nordström field, in which the curvature of spacetime is caused not only by the mass m, but also by the electric charge q.

Previously, we saw how the Nordström metric is derived in general relativity. This is done using various tensors and differential equations that describe the curvature of spacetime or Einstein's gravitational field. However, in what follows, we show that it is possible to derive the Nordström metric without using complex tensors. This means that we get exactly the same result even if tensor mathematics is not used. This means a much easier path to almost the same solution.

For example, the Schwarzschild radius R can be expressed from general relativity as:

$$R = \frac{2GM}{c^2}$$

Since mass and energy are mutually equivalent quantities, i.e. $E = mc^2$, we can express mass m only through energy E:

$$m = M = \frac{E}{c^2}$$

and therefore the expression for the Schwarzschild radius R becomes

$$R = \frac{2GE}{c^4}$$

Since the electric field of electric charge q has energy E or W:

$$W = E = \frac{1}{2}\frac{q^2}{4\pi\varepsilon_0 \varepsilon R} = \frac{q^2}{2C}$$

then we get the following expression, which shows the creation of a trapped surface in spacetime by an electric charge q:

$$R = \frac{q^2 G}{Cc^4}$$

Decomposing the latter equation, we get the following expression:

$$R_q = \frac{q^2 G}{4\pi\varepsilon_0 \varepsilon R c^4}$$

in which the capacitance C is in this case the capacitance of the sphere:

$$C = 4\pi\varepsilon_0\varepsilon R$$

Finally, we get an equation that shows the creation of a spherical trapped surface in spacetime by electric charge q:

$$R_q = \sqrt{\frac{q^2G}{4\pi\varepsilon_0\varepsilon c^4}}$$

The equations for the trapped surface in spacetime created by mass and electric charge are equal to each other:

$$R = \frac{2GM}{c^2} = \sqrt{\frac{q^2G}{4\pi\varepsilon_0\varepsilon c^4}}$$

In the well-known Schwarzschild metrics:

$$ds^2 = \left(1 - \frac{R_M}{r}\right)dt^2 - \frac{1}{1 - \frac{R_M}{r}}dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

the Schwarzschild radius R appears:

$$R_M = \frac{2GM}{c^2}$$

which is caused by the mass of the body M. However, from the latter expression it is also possible to mathematically derive the equation for the "Nordström" radius:

$$R_M = \frac{2GM}{c^2} = R_q = \sqrt{\frac{q^2G}{4\pi\varepsilon_0 c^4}} = \frac{q^2G}{4\pi\varepsilon_0 R_q c^4} = E_T\frac{G}{c^4}$$

which in turn would give us the following metric equation:

$$ds^2 = \left(1 - \frac{R_q}{r}\right)dt^2 - \frac{1}{1 - \frac{R_q}{r}}dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

Such a metric equation describes the curvature of spacetime caused only by the electric charge q. E_T is the electric field strength.

This result is slightly different from Nordström's metric equation obtained above. For example, there is no effect of mass on the spacetime metric, the sign of the Nordström radius is not positive, and the radii are not squared. In the following, we justify the emergence of the difference through a mathematical analysis, in which case we see that the Nordström metric obtained above, i.e. derived through tensors, cannot be valid in reality.

1.6.3 Nordström metrics

In the Schwarzschild metric derived above:

$$ds^2 = \left(1 - \frac{R_M}{r}\right)dt^2 - \frac{1}{1 - \frac{R_M}{r}}dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

appears the Schwarzschild radius R:

$$R_M = \frac{2GM}{c^2}$$

which is caused by the mass of the body M. However, from the latter expression it is also possible to mathematically derive the "Nordström" radius equation:

$$R_M = \frac{2GM}{c^2} = R_q = \sqrt{\frac{q^2 G}{4\pi\varepsilon_0 c^4}}$$

which in turn would give us the following metric equation:

$$ds^2 = \left(1 - \frac{R_q}{r}\right)dt^2 - \frac{1}{1 - \frac{R_q}{r}}dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

Such a metric equation describes the curvature of spacetime caused only by the electric charge q.

However, it is also possible to reach this result in another way. For example, from Schwarzschild's metric equation, the following equation is obtained as a result of specific tensor calculations in general relativity:

$$ds^2 = \left(1 - \frac{R}{r} + \frac{\beta^2}{r^2}\right)dt^2 - \frac{1}{1 - \frac{R}{r} + \frac{\beta^2}{r^2}}dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

in which R is the Schwarzschild radius and the electric charge q is related to β as follows

$$\beta^2 = \frac{\varkappa q^2}{8\pi c^2}$$

where the value of the constant $\varkappa$ in return is

$$\varkappa = \frac{2}{c^2}4\pi G = \frac{8\pi G}{c^2} = 1{,}86 * 10^{-26}$$

The unit here is SI. And finally, we can now write this first equation like this:

$$ds^2 = \left(1 - \frac{R}{r} + \frac{\varkappa q^2}{8\pi c^2 r^2}\right) dt^2 - \frac{1}{1 - \frac{R}{r} + \frac{\varkappa q^2}{8\pi c^2 r^2}} dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

in which the electric constant is taken as the unit

$$\frac{1}{4\pi\varepsilon_0} = 1$$

Let's analyze it a little. In the equation term in the parentheses expression:

$$+\frac{\beta^2}{r^2}$$

the square of β is equal to the equation:

$$\beta^2 = \frac{\chi q^2}{8\pi c^2}$$

Since the constant multiplier χ is expressed as follows:

$$\chi = \frac{8\pi G}{c^2}$$

we get the actual equation for the square of β:

$$\beta^2 = \frac{q^2}{8\pi c^2}\frac{8\pi G}{c^2} = \frac{q^2 G}{c^4}$$

or

$$\beta^2 = \frac{q^2 G}{c^4}$$

From the latter equation we see that β must equal:

$$\beta = \sqrt{\frac{q^2 G}{c^4}}$$

in which the electrical constant is equal to one:

$$\frac{1}{4\pi\varepsilon_0} = 1$$

However, if the dimension or unit of the electric constant is not one, then β is equal to the following equation:

$$\beta = \sqrt{\frac{q^2 G}{4\pi\varepsilon_0 c^4}} = r$$

Such a field (the square of the line element) is called the Nordström field. Here you can see that, in addition to mass, time and space are also bent by the electric charge of the body. This also shows that a black hole can also form from, for example, electrically charged matter. Electrically charged matter can also cause spacetime to warp. This equation also shows the formation of two horizons inside each other, which means that if a physical body has mass as well as electric charge, then it has two radii:

$$r_q = \sqrt{\frac{q^2 G}{4\pi\varepsilon_0 c^4}}$$

$$R_S = \frac{2GM}{c^2}$$

where R_s is the so-called Schwarzschild radius of the body and r_q is basically the same as R_s but is caused by the presence of electric charge. G is the gravitational constant and c is the speed of light in vacuum. M is mass, q is the charge of the body and ε_0 is the dielectric permittivity of (substance, vacuum). The equation for r_q can also be used to calculate the inner horizon radius field of a charged black hole.

The effect of electric charge on the structure of spacetime together with mass can be given an even simpler solution (equation), which is called the Reissner-Nordström metric:

$$ds^2 = -\left(1 - \frac{2M}{r} + \frac{Q^2}{r^2}\right) dt^2 + \left(1 - \frac{2M}{r} + \frac{Q^2}{r^2}\right)^{-1} dr^2 + r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

Such a solution is used when using units where the gravitational constant G and the speed of light in vacuum c both have a numerical value of 1 (ie c = G = 1). From the Nordström field, the so-called electromagnetic time dilation t and length contraction l mathematically derive as follows:

$$t = \frac{t_0}{\sqrt{1 - \frac{R}{r} + \frac{\beta^2}{r^2}}}$$

$$l = l_0 \sqrt{1 - \frac{R}{r} + \frac{\beta^2}{r^2}}$$

or in a transformed form

$$t = \frac{t_0}{\sqrt{1 - \frac{R}{r} + \frac{\varkappa q^2}{8\pi c^2 r^2}}}$$

and

$$l = l_0\sqrt{1-\frac{R}{r}+\frac{\varkappa q^2}{8\pi c^2 r^2}}$$

These equations very clearly show the curvature of spacetime (that is, the slowing down of time and the shortening of length), which is caused not only by the body's mass, but also by the body's electric charge. If we take c = G = 1 as the dimension, we can write these same equations as follows:

$$t = \frac{t_0}{\sqrt{1-\frac{2M}{r}+\frac{Q^2}{r^2}}}$$

and

$$l = l_0\sqrt{1-\frac{2M}{r}+\frac{Q^2}{r^2}}$$

In the Reissner-Nordström metric describing the curvature of spacetime

$$ds^2 = \left(1-\frac{R}{r}+\frac{\beta^2}{r^2}\right)dt^2 - \frac{1}{1-\frac{R}{r}+\frac{\beta^2}{r^2}}dr^2 - r^2(d\theta^2+sin^2\theta d\varphi^2)$$

the plus sign must change to a minus, because the Schwarzschild radius and the Nordström radius are always equal using the same energy (i.e. $E = mc^2$). This means that if the Schwarzschild radius indicates the size of a hole in spacetime in our spacetime, then the Nordström radius must also indicate it. This can be expressed only if there is a minus sign in the equation instead of a plus sign:

$$ds^2 = \left(1-\frac{R}{r}-\frac{\beta}{r}\right)dt^2 - \frac{1}{1-\frac{R}{r}-\frac{\beta}{r}}dr^2 - r^2(d\theta^2+sin^2\theta d\varphi^2)$$

or put parentheses in the equation instead:

$$ds^2 = \left(1-\left(\frac{R}{r}+\frac{\beta}{r}\right)\right)dt^2 - \frac{1}{1-\left(\frac{R}{r}+\frac{\beta}{r}\right)}dr^2 - r^2(d\theta^2+sin^2\theta d\varphi^2)$$

To prove the previous reasoning, we present a small physical analysis below. For example, on the Schwarzschild surface, time (and space) is transformed, i.e. curved to infinity according to the following equation:

$$t' = \frac{t}{\sqrt{1-\frac{R_S}{r}}} = \frac{t}{\sqrt{1-\frac{2GM}{rc^2}}}$$

Since from the equation for the Schwarzschild radius R_S

$$R_S = \frac{2GM}{c^2}$$

the equation for the radius R of a trapped surface in spacetime is mathematically directly derived:

$$R = \sqrt{\frac{q^2 G}{4\pi\varepsilon_0 c^4}}$$

which is caused by the electric charge q, therefore spacetime must also be transformed, i.e. curved to infinity, on this "surface":

$$t' = \frac{t}{\sqrt{1 - \frac{R}{r}}} = \frac{t}{\sqrt{1 - \sqrt{\frac{q^2 G}{4\pi\varepsilon_0 c^4}}\frac{1}{r}}}$$

This means that if in the previously presented equation

$$t' = \frac{t}{\sqrt{1 - \frac{R_S}{r} + \frac{{R_q}^2}{r^2}}}$$

the next term is practically zero, i.e. the effect of body mass on the spacetime metric is close to zero:

$$\frac{R_S}{r} \longrightarrow 0$$

then we see that the square root expression in the Reissner-Nordström metric equation does not correspond to reality:

$$t' = \frac{t}{\sqrt{1 + \frac{{R_q}^2}{r^2}}} \neq \frac{t}{\sqrt{1 - \frac{R_q}{r}}}$$

The only rational explanation for this can be that Reissner-Nordström probably considered the following when creating his metric equation:

$$\left(-\frac{R_q}{r}\right)^2 = +\frac{{R_q}^2}{r^2}$$

This means that the square root expression in the metric equation above has taken into account the square of the radius:

$$R_q{}^2 = \frac{q^2 G}{4\pi\varepsilon_0 c^4}$$

but not just the radius:

$$R_q = \sqrt{\frac{q^2 G}{4\pi\varepsilon_0 c^4}}$$

which would actually be more correct. Therefore, the actual square root expression should look like this:

$$t' = \frac{t}{\sqrt{1 - \frac{R_S}{r} - \frac{R_q}{r}}}$$

In the latter equation we see that if both quotients of the radii equal one:

$$t' = \frac{t}{\sqrt{1-1-1}} = \frac{t}{\sqrt{-1}} = \frac{t}{i}$$

then we get a complex number i, because $i = \sqrt{-1}$. A complex number is related to a complex equation z:

$$z = a + bi$$

where a is the real part of the equation and +bi is the imaginary part, a and b are real numbers. However, in this case we are only dealing with the imaginary part:

$$z - a = +bi$$

or $z = i$, where a = 0 and b = +1. Therefore, we get in the previously derived equation:

$$t' = \frac{t}{i}$$

write zero instead of the imaginary number and the result is an infinite time transformation:

$$t' = \frac{t}{0} = \infty$$

which exactly coincides with the physical nature of the trapped surface in spacetime, because on its "surface", spacetime is curved, or transformed, to infinity. Such an approach is allowed, because in physics only the real part of the equation is considered, not the imaginary part. In this case, the real part of our equation was zero. However, if we assume that only the following term is equal to one: $\frac{R_S}{r} = 1$, then we get the following:

$$t' = \frac{t}{\sqrt{1 - \frac{R_S}{r} + \frac{{R_q}^2}{r^2}}} = \frac{t}{\sqrt{1 - 1 + \frac{{R_q}^2}{r^2}}}$$

However, the latter obtained relation is again contrary to reality:

$$t' = \frac{t}{\sqrt{+\frac{{R_q}^2}{r^2}}} = \frac{t}{\frac{R_q}{r}} = \frac{t}{+1} = \frac{rt}{R_q} = t$$

This is because on the trapped surface in spacetime, time and space are curved or transformed to infinity, and it does not matter whether the mass of the body or the electric charge of the body is the cause of the trapped surface in spacetime.

From Nordström's metric, it appears that electric charge also bends spacetime in addition to mass. Human mass warps the surrounding spacetime, but this curvature is so small that it is practically impossible to measure. This means that if the effect of mass on spacetime is extremely small compared to the effect of charge (closer to zero), then it can be omitted in the equation:

$$ds^2 = \left(1 - \frac{\beta}{r}\right)dt^2 - \frac{1}{1 - \frac{\beta}{r}}dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

It is a metric of spacetime transformation due to purely electromagnetic interaction, in which the effect of mass is practically close to zero. Consequently, we can mathematically obtain the electromagnetic time dilation t and the electromagnetic length contraction l as follows:

$$t = \frac{t_0}{\sqrt{1 - \frac{\beta}{r}}}$$

and

$$l = l_0\sqrt{1 - \frac{\beta}{r}}$$

It is noteworthy to note that if it is only a gravitational field, i.e. only the effect of mass of the body on the spacetime metric, it is described by the Schwarzschild metric:

$$ds^2 = \left(1 - \frac{R}{r}\right)dt^2 - \frac{1}{1 - \frac{R}{r}}dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

However, if the spacetime metric is simultaneously affected by mass and electric charge, it is described by the Reissner-Nordström metric:

$$ds^2 = \left(1 - \frac{R}{r} - \frac{R_q}{r}\right)dt^2 - \frac{1}{1 - \frac{R}{r} - \frac{R_q}{r}}dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

However, if the spacetime metric is only affected by the electric charge of the body, then the following metric describes it:

$$ds^2 = \left(1 - \frac{R_q}{r}\right)dt^2 - \frac{1}{1 - \frac{R_q}{r}}dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

1.6.4 Trapped surface in spacetime and electric energy

In case of an electric charge, it must be taken into account that if the effect of the body's mass on the spacetime metric is inversely proportional to the radius, i.e. the distance from the mass, then in case of the body's electric charge it is inversely proportional to the square of the distance from the charge:

$$t' = \frac{t}{\sqrt{1 - \frac{R^2}{r^2}}}$$

The latter equation shows the time transformation caused by the electric charge, not the mass of the body. According to this, time has transformed, or warped to infinity:

$$t' = \frac{t}{\sqrt{1-1}} = \frac{t}{0} = \infty$$

that is, the multiplier y has an infinitely large value

$$\frac{t'}{t} = y = \infty$$

on the trapped surface in spacetime

$$R^2 = r^2$$

which is caused by an electric charge, not the mass of the body. This regularity follows from the fact that the equation for Schwarzschild radius R

$$R = \frac{2GM}{c^2}$$

which indicates the size of the trapped surface in spacetime (on the "surface" of which spacetime is curved to infinity), is a directly derived equation:

$$R^2 = \frac{q^2 G}{4\pi\varepsilon_0 c^4}$$

which shows that the electric charge, not the mass of the body, is the generator of the trapped surface in a given spacetime. Therefore, the physical nature of a trapped surface in spacetime is exactly the same in both cases:

$$R = \frac{2GM}{c^2} = \sqrt{\frac{q^2 G}{4\pi\varepsilon_0 c^4}}$$

in which it does not make much difference whether the mass of the body M or the electric charge q is the generator of the trapped surface in spacetime R. This means that in both cases a trapped surface in spacetime is created, on the "surface" of which spacetime is curved to infinity. This follows directly from the fact that mass m and energy E are mutually equivalent quantities in the relation:

$$E = mc^2$$

The Schwarzschild surface of a black hole, i.e. the trapped surface in spacetime, the size of which is determined by the radius R:

$$R = \frac{2GM}{c^2}$$

according to Albert Einstein's theory of general relativity, time and space are curved or transformed to infinity. It can also be interpreted as the entrance and exit of a tunnel in spacetime or wormhole. Since mass m and energy E are mutually equivalent quantities in the equation for static energy E:

$$E = mc^2$$

or

$$\frac{E}{c^2} = m = M$$

then we can also express the equation for the Schwarzschild radius R purely in terms of energy E:

$$R = \frac{2GM}{c^2} = \frac{2G}{c^2} M = \frac{2G}{c^2} \frac{E}{c^2} = \frac{2GE}{c^4} = \frac{2G}{c^4} E$$

If this energy turns out to be the energy of an electric field E:

$$E = \frac{q\varphi}{2} = \frac{q^2}{8\pi\varepsilon_0 r}$$

then we get the well-known equation for the Reissner-Nordström radius r:

$$R = \frac{2G}{c^4} E = \frac{2G}{c^4} \frac{q^2}{8\pi\varepsilon_0 r} = \frac{q^2 G}{4\pi\varepsilon_0 c^4} \frac{1}{r}$$

or

$$r^2 = \frac{q^2 G}{4\pi\varepsilon_0 c^4}$$

which describes the creation of a trapped surface in spacetime by electric charge q. Therefore, the following equality must also hold:

$$r = \sqrt{\frac{q^2 G}{4\pi\varepsilon_0 c^4}} = \frac{2GM}{c^2} = R$$

which means that the Schwarzschild radius R depends only on the mass of a body M, but the Reissner-Nordström radius r depends on the electric field energy E.

> Since an electric charge can influence the metric of spacetime, it is possible to create a tunnel in spacetime using electromagnetic interaction, which would allow traveling through time. The same principle has been cultivated by the world-famous scientist Michio Kaku, who is a professor of physics at the City University of New York. His idea involves two chambers, each containing two parallel metal plates. The principle is that a sufficiently powerful electromagnetic force is generated, which creates a strong electric field between the plates. This is about the level of the superfields generated by Tesla over a century ago when he was trying to create artificial lightning to power residential buildings. However, it is certainly interesting to remember that, according to Tesla, he experienced some form of time travel during his first experiments with such a gigantic electromagnetic field. The metal plates of Kaku's time machine must allow as powerful an energy field as the plates can handle. A superconductor developed for various antigravity experiments could become the key to enabling a strong enough energy field to open the door to time travel. If these conditions are in place, the machine must warp spacetime in the vicinity of the device in such a way as to create a wormhole connecting two adjacent chambers. The result should be a bridge through spacetime, hopefully stabilized by exotic matter produced by the Casimir effect. (10)

Suppose that the electric charge of some kind of body creates a horizon similar to a black hole with a radius of one meter. Let's calculate with the following equations how big the electric charge of this body must be:

$$r_q = \sqrt{\frac{q^2 G}{4\pi\varepsilon_0 c^4}}$$

or

$$q\ (C) = \sqrt{\frac{r^2 4\pi\varepsilon_0 c^4}{G}}$$

Making calculations according to the latter equation, we get the charge of a body q to be 1,16 * 10^{17} coulombs, or C, if the radius r is 1 meter and the dielectric permittivity ε_0 is approximately 1. This amount of energy, or in this case electric charge q

$$q = \sqrt{E(8\pi\varepsilon_0\varepsilon R)} = 1{,}16 * 10^{17}\ C$$

it cannot be obtained from anywhere, nor can it be created artificially. Therefore, it is not realistically possible to create tunnels in spacetime through which you can travel through time "in this way".

> In order to warp spacetime, a very large electric charge is needed, but the electric charge of a body cannot be infinitely large, because then repulsive forces will appear between the charges, which would prevent spacetime from warping. In the same way, the electric capacity of a body does not allow it to have an infinitely large charge. For example, on a capacitor, or in the space between two oppositely charged surfaces, the energy of an electric field is very small (the field potentials are also very small), but at the same time there are very large electric charges and field strengths. For example, if the capacitance of a capacitor is 0.6 mF and its charge is 0.12 C, then the capacitor has an energy of "only" 12 J.

The size (radius R) of a body carrying the electric charge calculated above (10^{17}coulombs) must be many times larger than the planet Earth. Such a charge could not be sustained on the surface of a smaller body (for example, a human), because then the repulsive forces between the charges would start to act. This shows that a very large electric charge is actually needed to warp spacetime, but the electric charge of a body cannot be infinitely large, because then repulsive forces begin to appear between the charges. In the same way, the electric capacity of the body does not allow it to have infinitely large charge. Here we highlight the following examples:

1. The sphere must have a radius of 54.7 meters in order for an electric charge of 1 coulomb to remain on it. The field strength of a charge of 1 C in vacuum at a distance of 1 m is 9 * 10^9 V/m.

2. A loose globe the size of planet Earth has a capacitance of 700 μF. However, a loose ball with a radius of 9 * 10^9 m, or about 1500 times the radius of Earth, has a capacitance of 1 F.

3. At the same time, a capacitance of 1 F is also formed by two square plates of the same size, the distance between each other is 1 mm, and the length of the edge of the plate is "only" 10 km.

4. In the membrane of a living cell, the field strength during rest is 2 * 10^7 V/m, while at the same time it is 5 * 10^{11} V/m at the location of an electron belonging to a hydrogen atom. The strengths of the biocurrents of living organisms are mostly below 10^{-6} A.

5. The thickness of the nerve fiber wall is 3 nm. The strength of the electric field in it at rest is 2.3 * 10^7 V/m. The resting potential of the inner part of the nerve fiber is -70 mV.

6. Two 1 C charges exert a force of 1 N on each other when they are approximately 95 km apart. 1 N is equal to the force of gravity acting on a body with a mass of 100 g. However, if their distance is 1 m, then this force is 9 * 10^9 N. Such a force is equal to the gravity of a body whose mass is almost a million tons.

In order to create a hole in spacetime, a very large electrical energy, or electric charge, is required, but the body's electric charge cannot be infinitely large, because then repulsive forces will appear between the charges, which would prevent the creation of a hole in spacetime. In the same way, the electric capacitance C of a body does not allow it to have infinitely large charge. For example, on a capacitor, or in the space between two oppositely charged surfaces, the energy of the electric field is very small (the field potentials are also very small), but at the same time there are very large electric charges and field strengths. For example, if a capacitor has a capacitance of 0.6 mF and a charge of 0.12 C, then the capacitor has "only" 12 J of energy. Electric field strengths can be very large on very small spatial scales—much, much larger than macroscopic fields can ever be. For example, at the location of an electron in a hydrogen atom, the field strength is $5 * 10^{11}$ N/C, in the membrane of a living cell (at res t) $2 * 10^{7}$ N/C, when a spark occurs in dry air it is $3 * 10^{6}$ N/C, and in the air immediately before a lightning strike it is up to $5 * 10^{5}$ N /C and the filament of a burning electric lamp has a field strength of 400 - 700 N/C.

The electric capacity C increases without limit, if, for example, the specially charged plates of a plate capacitor are practically brought together in such a way that the distance between the plates decreases without limit. In theory, this is possible. However, in case of polarization of electric charges, the smallest known distance between the positive and negative charge is between the nucleus of an hydrogen atom (i.e. a proton) and an electron, which is in the order of about 10^{-10} m. However, for example, the distance between two protons or two positive charges in helium nucleus is even smaller (the order of magnitude is about $10^{-15}...10^{-16}$ m). A negative charge can be an ion or an electron, but a positive charge is always an ion (except for protons). Protons are not actually single particles (like electrons are), but they are made up of quarks.

In order to create a hole in spacetime, a very large electrical energy, or electric charge, is required, but the body's electric charge cannot be infinitely large, because then repulsive forces will appear between the charges, which would prevent the creation of a hole in spacetime. In the same way, the electric capacitance C of a body does not allow it to have infinitely large charge. Any charge q is formed from elementary charges, that is, it is an integral multiple of the elementary charge e:

$$q = \pm Ne$$

$$q = Ne$$

and thus we get the charge concentration N

$$N = \frac{q}{e}$$

If the charge q is $1.17 * 10^{17}$ (C) and e is the elementary charge $1.60 * 10^{-19}$ (C), then we get the charge concentration N to be $7.34 * 10^{35}$. This number tells us how many elementary charges, that is, e's (e.g. electrons) are needed to generate the corresponding charge q. This number can also indicate the number of particles. Since this number is really very large, let's give some examples of charge concentrations for comparison:

1. In the filament of a flashlight (if the area S is equal to $3 * 10^{-10}$ m^2 and the current strength I is 0.3 A), the concentration of charge carriers is $1.3 * 10^{29}$ m^{-3}.

2. There are $8.5 * 10^{22}$ conduction electrons in one cubic centimeter of copper, if the density of copper is 8960 kg/m^3, the molar mass is 63.5 g/mol, the cross-sectional area S of the copper wire is 1 mm^2, and the current is 1 A. There is one conduction electron for each copper atom.

3. However, the concentration of free electrons in metal can also be 10^{29} m^{-3}.

If one electron is released from each atom, then the concentration of electrons (the number of electrons n per unit volume) is equal to the number of atoms per unit volume. Let's calculate the value of n. The number of atoms per unit volume is

$$\frac{\delta}{\eta} N_A$$

where δ is, for example, the density of the metal and η is the mass of a kilogram atom. Avogadro's number is N_A. For metals, the δ/η value is between 20 $kmol/m^3$ (potassium) and 200 $kmol/m^3$ (beryllium). This gives an order of magnitude for the concentration of free electrons

$$n = 10^{28} \ldots 10^{29}\ m^{-3}\ (10^{22} \ldots 10^{23}\ cm^{-3})$$

The space charge density ρ, surface density σ and line density λ can be calculated as follows:

$$\rho = \lim_{\Delta V \to 0} \frac{\Delta q}{\Delta V}, \qquad \sigma = \lim_{\Delta S \to 0} \frac{\Delta q}{\Delta S}, \qquad \lambda = \lim_{\Delta l \to 0} \frac{\Delta q}{\Delta l}$$

1.6.5 Geometric shape of a trapped surface in spacetime

According to Albert Einstein's theory of general relativity, the Schwarzschild surface (or "a hole in spacetime") that exists at the center of gravity is almost always completely spherical. Equipotential surfaces are important in the electric field to create a hole in spacetime. This means that a hole in spacetime occurs along the equipotential surface of the field (the shape of the hole in spacetime depends on the shape of the equipotential surface of the field) and therefore the hole in spacetime does not have to be completely spherical like in case of gravity, but very different from it. For example, in the shape of a person. If the surface of a sphere (i.e. a spherical physical body or object) is electrically charged, then the event horizon created by the electric charge arises according to the following equation:

$$R = \sqrt{\frac{q^2 G}{4\pi\varepsilon_0 c^4}}$$

In case of a sphere, it is a centrally symmetric electric field. $\frac{1}{4\pi\varepsilon_0}$ is a ratio known from Coulomb's law, in which ε_0 is an electric constant. According to the definition of electric capacity $C = \frac{q}{U}$, we can write the electric charge as follows: $q = CU$. Thus, in case of the capacity of a sphere, we get the radius of the event horizon:

$$R = \sqrt{\frac{(4\pi\varepsilon R_1 U)^2 G}{4\pi\varepsilon_0 c^4}}$$

or

$$R = \sqrt{\frac{\left(\frac{4\pi\varepsilon U}{\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}\right)^2 G}{4\pi\varepsilon_0 c^4}}$$

The capacitance of a charged sphere is $C = 4\pi\varepsilon R_1$, where ε is the dielectric permittivity and R_1 is the radius of the sphere. However, if the surface of the sphere is electrically polarized, then the electric capacitance of the sphere is

$$C = \frac{4\pi\varepsilon}{\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$$

where ε is dielectric permittivity and R_1 is the radius of the inner sphere and R_2 is the radius of the outer sphere. The latter Nordström radius equation is only valid for a spherical body. The radius R indicates the size of the trapped surface of the event horizon:

$$4\pi R^2 = \frac{(CU)^2 G}{\varepsilon_0 c^4}$$

or

$$4\pi r^2 = \frac{q^2 G}{\varepsilon_0 c^4}$$

in which $4\pi R^2$ is the size of the trapped surface, which in this case is the shape of the surface of a sphere S. However, instead of the surface of the sphere S in the equation, we can put the equation for the surface of any shape and thus we can write out a much more general equation:

$$S = \frac{(CU)^2 G}{\varepsilon_0 c^4}$$

or

$$S = \frac{q^2 G}{\varepsilon_0 c^4}$$

The latter equation is valid for a body with any surface shape, i.e. it is a general equation in which the trapped surface in spacetime can be of any shape and size. Here, it must be taken into account that the electric capacitance C of the body must correspond to the shape of the trapped surface S. For example, in case of a spherical body, a spherically shaped trapped surface is created. In this case, we need to use the equations for the capacitance of a sphere to find the magnitude of the charge on the sphere.

The dependence of the geometric shape of a trapped surface in spacetime on the shape of the equipotential surface of the electric field can be proven by the following mathematical analysis. To do this, in the equation for trapped surface in spacetime

$$r = \sqrt{\frac{q^2 G}{4\pi\varepsilon_0 c^4}}$$

we will square both sides of the equation

$$r^2 = \frac{q^2 G}{4\pi\varepsilon_0 c^4}$$

Let's move the basic physical constants c and G and the electric charge q to one side of the equation

$$\frac{c^4}{Gq} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} = E_T$$

and we see that we have derived the electric field strength equation directly from the equation for a trapped surface in spacetime:

$$E_T = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

Previously, it could be seen that

$$\frac{c^4}{Gq} = E_T$$

Derived from the relation

$$E_T = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

it is a centrally symmetric surface:

$$S = 4\pi r^2$$

Thus we obtain the equation

$$S = \frac{q}{E_T \varepsilon_0}$$

or

$$E_T = \frac{q}{\varepsilon_0 S}$$

in which it can be seen that the surface area S does not have to be spherical, but can be of any shape. If we could mathematically derive directly from the equation for the trapped surface in spacetime

$$r = \sqrt{\frac{q^2 G}{4\pi\varepsilon_0 c^4}}$$

the equation for electric field strength

$$E_T = \frac{q}{\varepsilon_0 S}$$

then this proves that the geometrical shape of an emerging trapped surface in spacetime really depends on the shape of the charged surface, because the strength of the electric field in the vicinity of a charged body also depends on the shape of the charged surface. In the previously derived relation:

$$\frac{c^4}{G} = E_T q$$

the product of electric field strength and electric charge is defined as electric force F:

$$F = E_T q$$

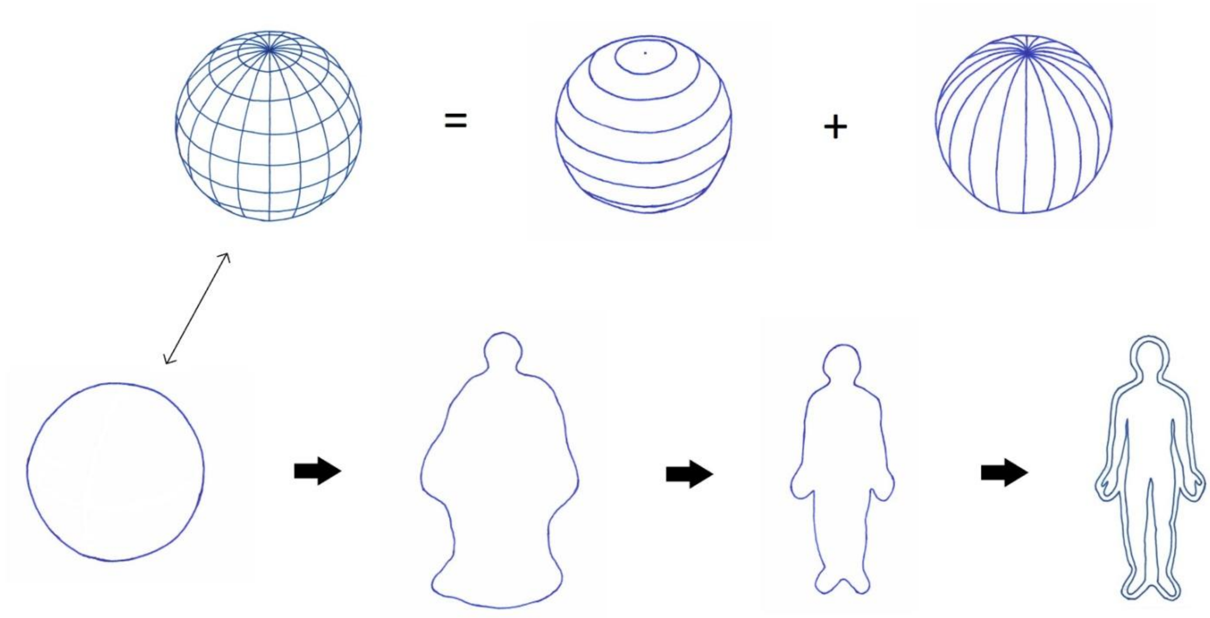
Therefore, we obtain the latter equation in the following form:

$$\frac{c^4}{G} = F$$

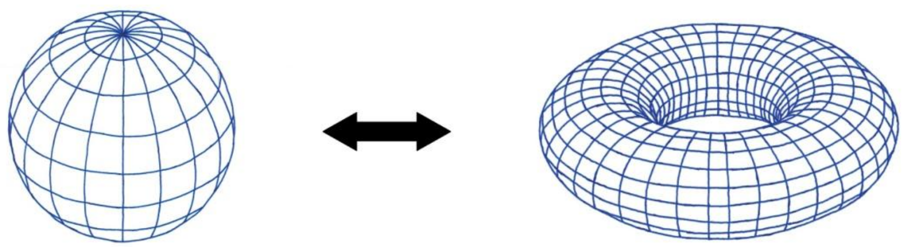
where we can see that electric force F coincides with the projection of field strength from a charged surface:

$$\frac{c^4}{G} = \frac{q^2}{\varepsilon_0 S} = F$$

In case of gravity, the hole in spacetime is spherical. However, in an electric field, its shape depends on the shape of the equipotential surface, and thus it can even be human-shaped. Figure:



The geometric shape of the trapped surface in spacetime can also be in the shape of a loop or donut:



1.7 The metric of a tunnel in spacetime

A centrally symmetric and static gravitational field is described by the Schwarzschild metrics:

$$ds^2 = \left(1 - \frac{R}{r}\right)c^2dt^2 - \frac{1}{1 - \frac{R}{r}}dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

or

$$ds^2 = -\left(1 - \frac{R}{r}\right)c^2dt^2 + \frac{1}{1 - \frac{R}{r}}dr^2 + r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

The expression in this equation:

$$\frac{dr^2}{\left(1 - \frac{R}{r}\right)} = dl^2$$

or

$$\frac{l^2}{\left(1 - \frac{R}{r}\right)} = {l_0}^2$$

can be considered as an expression for gravitational space contraction:

$$l^2 = {l_0}^2\left(1 - \frac{R}{r}\right)$$

or

$$l = l_0\sqrt{1 - \frac{R}{r}}$$

Therefore, we can use the Schwarzschild metric equation presented above:

$$ds^2 = -\left(1 - \frac{R}{r}\right)c^2dt^2 + \frac{1}{1 - \frac{R}{r}}dr^2 + r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

written in the following form:

$$ds^2 = -\left(1 - \frac{R}{r}\right)c^2dt^2 + dl^2 + r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

in which

$$dl^2 = \frac{dr^2}{1 - \frac{R}{r}}$$

The temporal part of the Schwarzschild metric is represented as follows:

$$ds^2 = c^2d\tau^2 = -\left(1 - \frac{R}{r}\right)c^2dt^2$$

or

$$d\tau^2 = -\left(1 - \frac{R}{r}\right)dt^2$$

It would be gravitational time dilation. We write the y-factor in the expression in the following form:

$$\frac{d\tau^2}{dt^2} = -\frac{1}{y^2} = -\left(1 - \frac{R}{r}\right) = -\left(1 - \frac{2GM}{rc^2}\right) = -\left(1 + \frac{2\Phi}{c^2}\right)$$

in which R is the Schwarzschild radius:

$$R = \frac{2GM}{c^2}$$

and Φ is gravitational potential:

$$\Phi = -\frac{GM}{r}$$

Since the gravitational potential is negative in physics, we can therefore use the imaginary unit i:

$$\Phi = -\frac{GM}{r} = +\frac{GM}{r}i^2$$

The imaginary unit i is defined in higher mathematics as follows:

$$i^2 = -1$$

If the imaginary unit i is used in the equations, then it is a complex number z:

$$z = a + bi$$

According to this definition, we can use the expression inside the parentheses:

$$\frac{d\tau^2}{dt^2} = -\left(1 - \frac{2GM}{rc^2}\right)$$

or

$$-\frac{d\tau^2}{dt^2} = 1 - \frac{2GM}{rc^2}$$

define as a complex number z:

$$z = 1 + \frac{2}{c^2}\frac{GM}{r}i^2 = 1 + \frac{2\Phi}{c^2}$$

The real part in it corresponds to number 1:

$$a = 1$$

and the imaginary part includes the imaginary unit i:

$$bi = \frac{2}{c^2}\frac{GM}{r}i^2$$

The trigonometric representation of the complex number z is presented in mathematics as follows:

$$z = a + bi = r(cos\varphi + isin\varphi)$$

in which the expression in parentheses is in turn related to the exponential form:

$$cos\varphi + isin\varphi = e^{i\varphi}$$

This also gives the complex number z exponential form:

$$z = r(cos\varphi + isin\varphi) = re^{i\varphi}$$

or

$$z = re^{i\varphi}$$

Since the y-factor may contain an imaginary unit i:

$$\frac{1}{y^2} = 1 - \frac{2GM}{c^2 r} = 1 + \frac{2GM}{c^2 r}i^2 = 1 + \frac{2\Phi}{c^2}$$

then there are actually three ways to write out the complex number z:

1. $re^{i\varphi} = z = 1 + \frac{2\Phi}{c^2}$

2. $1 + \frac{2\Phi}{c^2} = 1 + z$

3. $1 + \frac{2\Phi}{c^2} = 1 + \frac{z}{c^2}$

According to the first of these, we would get, for example, the metric equation in the following form:

$$ds^2 = -re^{i\varphi}c^2dt^2 + dl^2 + r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

But this would also mean that, according to the first possibility, the real part of the equation for a complex number:

$$z = a + bi$$

would be equal to one: a = 1 and in other possibilities it would be equal to zero. But we do not use the exponent form of a complex number here. Instead, we use Euler's equation:

$$e^z = \lim_{n\to\infty}\left(1+\frac{z}{n}\right)^n$$

This is the Euler limit known in mathematics and used in physics. In the following, we show that this equation actually occurs in Schwarzschild's metric equation. To do this, we perform the following mathematical transformations. For example, in the given equation (without lim):

$$e^z = \left(1+\frac{z}{n}\right)^n$$

we take the square root of both sides of the equation:

$$\sqrt[n]{e^z} = 1+\frac{z}{n}$$

and then we multiply both sides of the equation by n:

$$e^z = n + z$$

If $n = 1$ and complex number z can be expressed:

$$z = a + bi = 0 + bi = bi = \frac{2}{c^2}\frac{GM}{r}i^2 = \frac{2\Phi}{c^2}$$

then we can present the $\frac{1}{y^2}$ factor in the Schwarzschild metric purely as an Euler formula:

$$e^z = 1+\frac{2}{c^2}\frac{GM}{r}i^2$$

or

$$e^z = 1+\frac{2\Phi}{c^2}$$

If we now compare the latter obtained equation with the Euler limit presented above:

$$e^z = \lim_{n\to\infty}\left(1+\frac{z}{n}\right)^n$$

then we see the relation: $z = 2\Phi$. Consequently, we can write the Schwarzschild's metric equation:

$$ds^2 = -\left(1 + \frac{2\Phi}{c^2}\right)c^2dt^2 + dl^2 + r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

in the following form:

$$ds^2 = -e^z c^2dt^2 + dl^2 + r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

or

$$ds^2 = -e^{2\Phi} c^2dt^2 + dl^2 + r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

in which $e^{2\Phi}$ is the Euler equation. The resulting metric equation is actually no longer the Schwarzschild metric describing the gravitational field, but it now describes a tunnel in spacetime tunnel, or wormhole.

The resulting tunnel in spacetime metric equation:

$$ds^2 = -e^{2\Phi} c^2dt^2 + dl^2 + r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

or

$$ds^2 = -e^{2\varphi_\pm(r)}dt^2 + \left(1 - \frac{b_\pm(r)}{r}\right)^{-1} dr^2 + r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

describes a static wormhole that a person can pass through. Shape function b(r)

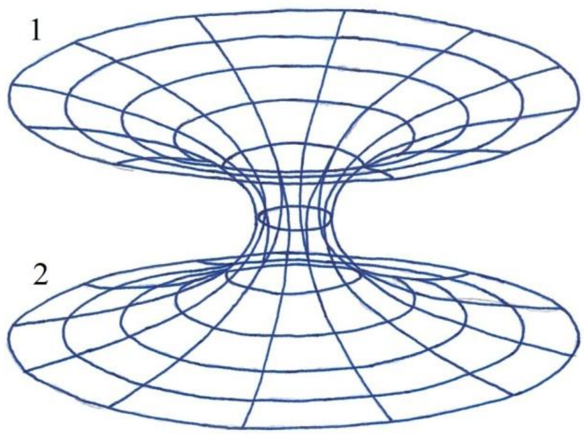
$$\frac{dl}{dr} = y = \pm\frac{1}{\sqrt{1 - \frac{b}{r}}} = \pm\left(1 - \frac{b}{r}\right)^{-\frac{1}{2}}$$

and the function of redshift $\Phi(r)$

$$\Phi = -\frac{GM}{r} = +\frac{GM}{r}i^2$$

determine a solution that is spherically symmetric. This means that the wormhole is spherical in reality. Figure:

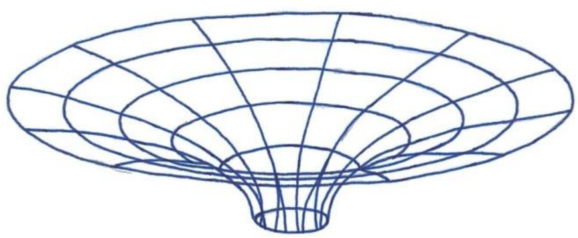
However, the wormhole is still depicted as a tunnel in the models. In this case, it is better to see that this solution connects two flat regions of spacetime (one positive, the other negative). Figure:



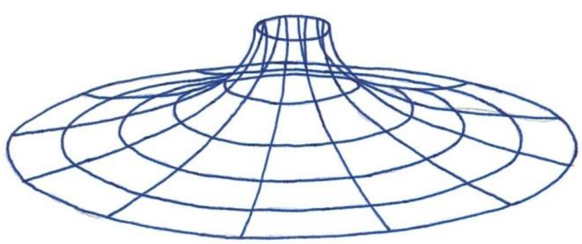
From the throat of the wormhole, l indicates the radial eigendistance, which means that l does not indicate the length of the tunnel, but it still describes the contraction of space around the tunnel in spacetime tunnel:

$$dl = \pm \frac{dr}{\sqrt{1-\frac{R}{r}}}$$

The contraction of space creates a tunnel in spacetime. For example, l is positive in the first connected region of spacetime:



and negative in the other connected region of spacetime:



Positive and negative l creates the effect of tunnel in spacetime that we see in the drawings. For example, the wormhole metric equation obtained above:

$$ds^2 = -e^{2\Phi}c^2dt^2 + dl^2 + r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

the areas of change are the following:

time:

$$-\infty < t < +\infty$$

radial coordinate:

$$-\infty < l < +\infty$$

and angle variables:

$$0 \leq \theta \leq \pi$$

$$0 \leq \varphi \leq 2\pi$$

In the first connected spacetime region, l is positive, which means that it is real. But in another connected spacetime region, l is negative, which means it is imaginary. If the real part of the equation were equal to zero, it would not be possible to draw physical conclusions. Physical phenomena or laws can only be described by the real part of the equation.

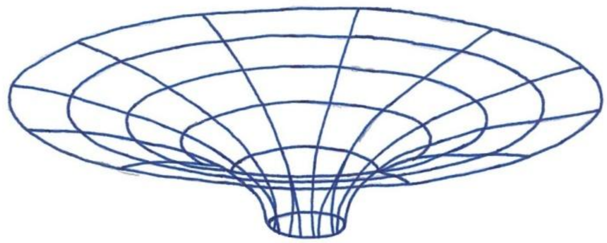
For example, the Schrödinger equation

$$-\frac{h^2}{2m}\Delta\Psi + U\Psi = ih\frac{d\Psi}{dt}$$

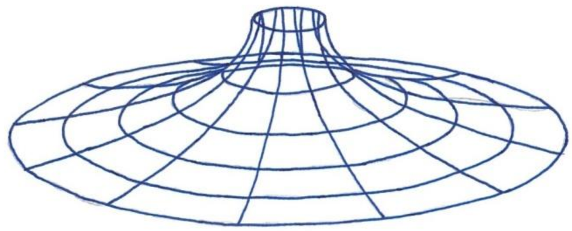
contains an imaginary unit, and thus all solutions of this equation generally have complex-numbered values. Only the real part of the equation needs to be considered. It is not possible to rank complex numbers. Complex numbers in physics themselves do not actually have any physical meaning, but only derive from mathematics. Many physics equations are often written in complex form, because then it is easier to perform calculations (such as derivations and integration). Since the Schrödinger equation is the fundamental equation of quantum mechanics, which is also in complex form, almost all other mathematical expressions of quantum mechanics are also complex.

If the real part of the equation of a complex number is equal to zero, then it cannot describe the laws of physics, because physical phenomena or laws can only be described with the real part of the equation. But positive and negative, or real and imaginary l, create the effect of a tunnel in spacetime that we see on the figures. In the real world, only the real l is realized, in which case the gravitational fields known to us exist in the universe. However, the imaginary part does not materialize in reality, and therefore it is believed that wormholes remain more in the realm of science fiction.

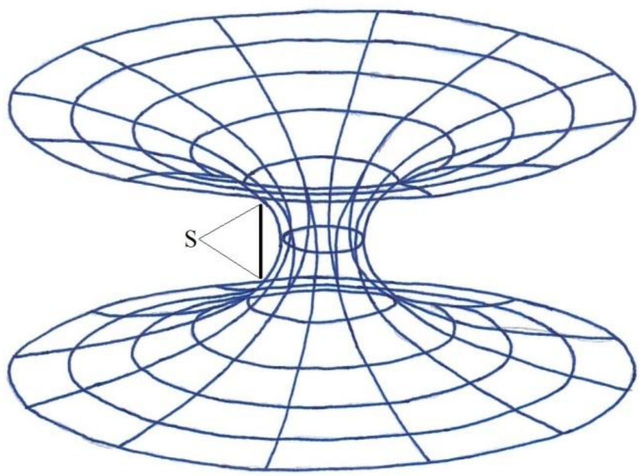
The imaginary part is not really that important, since the imaginary part already overlaps with the dimension of hyperspace. Hyperspace is an imaginary space in which you can travel through time. This means that instead of a tunnel in spacetime, we are looking at a hole in spacetime, which is real and can be physically interpreted as a "window" or a "gate" through which it is possible to reach hyperspace. Through the hole in spacetime you can move from normal space to hyperspace and from hyperspace to normal space. It can also be interpreted in this way that the real l indicates "exiting the normal space":



and the imaginary l shows “entering the hyperspace”:

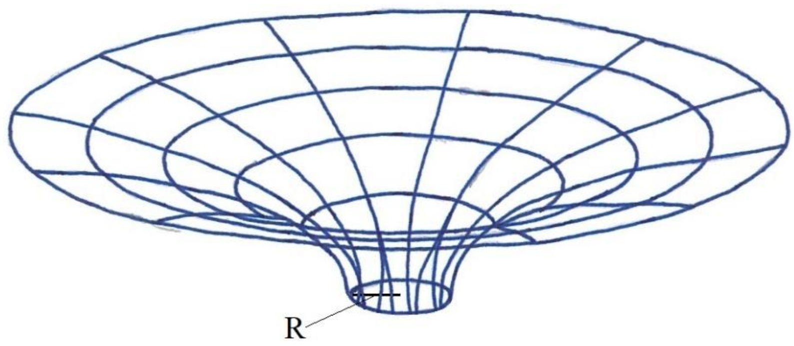


This would be the most accurate interpretation. Parameter or expression describing the length of the tunnel s:



we can't really find the spacetime tunnel metrics.

But here it is important to note that a tunnel in spacetime is created by a hole in spacetime, i.e. a tunnel in spacetime is created around a hole in spacetime, because spacetime is curved around the hole in spacetime. On the "surface" or "edge" of the hole in spacetime, spacetime is curved to infinity. Figure:



The size of the hole in spacetime in spacetime is indicated by its radius R:

$$R = \frac{2GM}{c^2}$$

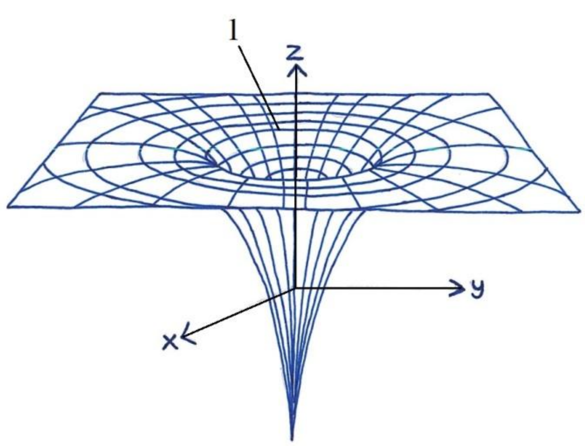
which, in this case, coincides with the expression for the Schwarzschild radius.

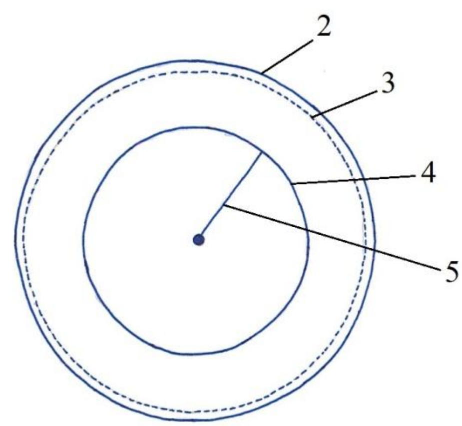
1.8 Other wormhole metrics in physical sciences

The statement of the Schwarzschild metrics describing gravitational field is as follows (without constants):

$$ds^2 = \left(1 - \frac{2M}{r}\right) dt^2 - \left(1 - \frac{2M}{r}\right)^{-1} dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

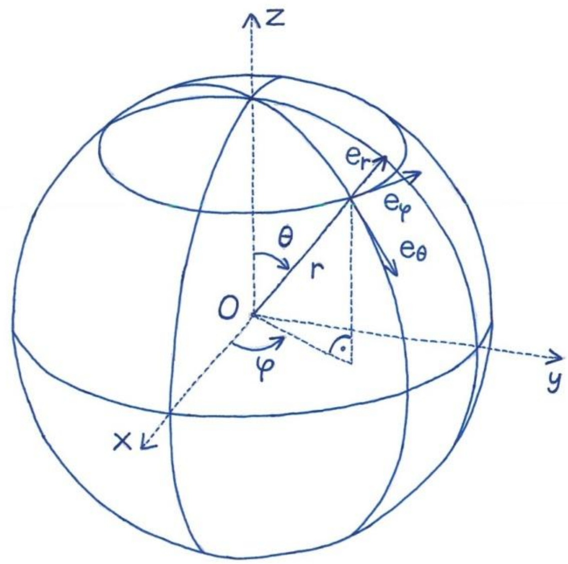
A Schwarzschild black hole with an accretion disk shown in the figure on the right (in the photon-sphere, the gravitational field forces photons to move in orbits):





1. Event horizon
2. Accretion disc
3. Photon sphere
4. Event horizon
5. Schwarzschild radius

Line element ds^2 is usually expressed in spherical coordinates:



If we use such a coordinate system:

$$v = t + r + 2Mln(r - 2M)$$

$$w = t - r - 2Mln(r - 2M)$$

then it will give Schwarzschild metrics in the following form:

$$ds^2 = \left(1 - \frac{2M}{r}\right) dvdw$$

This includes derivatives of the coordinates:

$$v'(v) = e^{\frac{v}{4M}}$$

$$w'(w) = -e^{-\frac{w}{4M}}$$

The shape of such metrics can also be written in a much longer way:

$$ds^2 = \frac{16M^2}{r} e^{-\frac{r}{2M}} (dt'^2 - dx'^2) - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

in which the expression in parenthesis equals in the following way:

$$t'^2 - x'^2 = (2M - r)e^{\frac{r}{2M}}$$

This includes derivatives of the coordinates:

$$t' = \frac{1}{2}\left(e^{\frac{v}{4M}} - e^{-\frac{w}{4M}}\right)$$

$$x' = \frac{1}{2}\left(e^{\frac{v}{4M}} + e^{-\frac{w}{4M}}\right)$$

or

$$t' = \frac{1}{2}(v' + w')$$

$$x' = \frac{1}{2}(v' - w')$$

This means that in the metrics of spacetime, yet another metric equation is presented:

$$ds^2 = \frac{16M^2}{r}e^{-\frac{r}{2M}}dt'^2 - \frac{16M^2}{r}e^{-\frac{r}{2M}}dx'^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

or

$$ds^2 = \frac{16M^2}{r}e^{-\frac{r}{2M}}(dt'^2 - dx'^2) - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

which describes a tunnel in spacetime or wormhole. Such a metrics is effectively equivalent to the Schwarzschild metrics. We will show this in the following. For example, the latter expression is written as follows:

$$ds^2 = \frac{16M^2}{r}e^{-\frac{r}{2M}}(2M - r)e^{\frac{r}{2M}} - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

In the metric equation, there is an expression:

$$\frac{16M^2}{r}e^{-\frac{r}{2M}}(2M - r)e^{\frac{r}{2M}} = \left(\frac{32M^3}{r} - 16M^2\right)e^{-\frac{r}{2M}}e^{\frac{r}{2M}}$$

In this equation, the following equals one:

$$e^{-\frac{r}{2M}}e^{\frac{r}{2M}} = e^0 = 1$$

and we can make the following transformations:

$$\frac{32M^3}{r} - 16M^2 = 16M^2\left(\frac{2M}{r} - 1\right)$$

In the equations, we have to take into account that the missing constants, that is, the equations are not presented in the SI system. So we present the equations in the SI system:

$$16M^2 \rightarrow \frac{16G^2M^2}{c^4} = \left(2\frac{2GM}{c^2}\right)^2 = (2r)^2 = l^2$$

and

$$\frac{2M}{r} - 1 \rightarrow \frac{2GM}{rc^2} - 1 = \frac{R}{r} - 1$$

Consequently, we can write the expression in the following form:

$$16M^2\left(\frac{2M}{r} - 1\right) \rightarrow l^2\left(\frac{R}{r} - 1\right)$$

For the sake of further analysis, let us assume that the following equation is true:

$$l^2 = l^2\left(\frac{R}{r} - 1\right)$$

We will prove this in the following. Let's move all members to the other side of the equals sign:

$$\frac{l^2}{l^2} - \frac{R}{r} + 1 = 0$$

As a result, we obtain:

$$1 - \frac{R}{r} = -\frac{l^2}{l^2}$$

or

$$l^2 = -\frac{1}{\left(1 - \frac{R}{r}\right)}l^2$$

The resulting relation already resembles a metric equation:

$$ds^2 = -\frac{1}{1 - \frac{R}{r}}dr^2$$

if we were to present it in a much longer way:

$$ds^2 = -\frac{1}{1 - \frac{R}{r}}dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

Such a metric equation describes an interval in space. An interval in time and space is described by the following metric equation:

$$ds^2 = \left(1 - \frac{R}{r}\right)c^2dt^2 - \frac{1}{1 - \frac{R}{r}}dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

This is the Schwarzschild metric equation that describes gravitational field. The previous analysis showed that the equation describing a wormhole:

$$ds^2 = \frac{16M^2}{r} e^{-\frac{r}{2M}}(dt'^2 - dx'^2) - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

is also derivable from the Schwarzschild metrics.

However, we do not use such a metric shape of wormholes in this work, as it does not correspond to reality. It is only a mathematical possibility, not a physical reality. In this work, we only use the metric form describing such a wormhole:

$$ds^2 = e^{2\varphi_\pm(r)}dt^2 - \left(1 - \frac{b_\pm(r)}{r}\right)^{-1} dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

which was already explained and analysed at length above.

However, we derived the form of the resulting metric that describes a wormhole from such metrics that describes the gravitational field. This means that metrics describing a wormhole is mathematically derived from the Schwarzschild metrics. Consequently, all parts of the metrics describing a wormhole must reduce mathematically to parts of the Schwarzschild metrics. This is also true in the opposite case. We will show and prove this in the following.

For example, above we were able to write the Schwarzschild metric equation:

$$ds^2 = -\left(1 + \frac{2\Phi}{c^2}\right)c^2dt^2 + dl^2 + r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

in the following form:

$$ds^2 = -e^z c^2dt^2 + dl^2 + r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

in which the complex number equalled:

$$z = 1 + \frac{2\Phi}{c^2}$$

or

$$z = 2\Phi$$

However, we can actually apply such logic here as well:

$$(2M - r)e^{\frac{r}{2M}} = 2Me^{\frac{r}{2M}} - re^{\frac{r}{2M}} =$$

$$= r - \frac{r^2}{2M} = r\left(1 - \frac{r}{2M}\right) = r\left(1 - \frac{c^2r}{2GM}\right) = r\left(1 - \frac{R}{r}\right)$$

In the equations, we have to take into account that the missing constants, that is, the equations are not presented in the SI system. Thus, here and hereafter we present all equations in the SI system as follows:

$$r\left(1-\frac{r}{2M}\right)=r\left(1-\frac{c^2r}{2GM}\right)=r\left(1-\frac{R}{r}\right)$$

Such a mathematical transformation has also been performed in the latter:

$$r\left(1-\frac{r}{R}\right)\rightarrow r\left(1-\frac{R}{r}\right)$$

The expression appearing in the metric equation above:

$$t'^2-x'^2=(2M-r)e^{\frac{r}{2M}}$$

can be written as follows:

$$(2M-r)e^{\frac{r}{2M}}=2Me^{\frac{r}{2M}}-re^{\frac{r}{2M}}=$$

$$=r-\frac{r^2}{2M}=r\left(1-\frac{r}{2M}\right)=r\left(1-\frac{c^2r}{2GM}\right)=r\left(1-\frac{R}{r}\right)$$

If we postulate the following equation:

$$r\left(1-\frac{R}{r}\right)=l\left(1-\frac{R}{r}\right)=\frac{l'^2}{l}$$

then we will see that the resultant relation:

$$l'^2=l^2\left(1-\frac{R}{r}\right)$$

or

$$l'=l\sqrt{1-\frac{R}{r}}$$

exactly coincides with the gravitational length contraction equation.

There is an expression for the radius r in the equations:

$$r=2M\left[1+W_0\left(\frac{x'^2-t'^2}{e}\right)\right]$$

This expression also eventually reduces to the Schwarzschild radius equation. We will show this in the following. For example, since the equation was given above:

$$t'^2-x'^2=(2M-r)e^{\frac{r}{2M}}=2Me^{\frac{r}{2M}}-re^{\frac{r}{2M}}$$

then we can write the expression in parentheses in the form:

$$\frac{x'^2-t'^2}{e}=\frac{re^{\frac{r}{2M}}-2Me^{\frac{r}{2M}}}{e}=\frac{re^{\frac{r}{2M}}}{e}-\frac{2Me^{\frac{r}{2M}}}{e}=re^{\frac{r}{2M}}e^{-1}-2Me^{\frac{r}{2M}}e^{-1}$$

or

$$re^{\frac{r}{2M}}e^{-1} - 2Me^{\frac{r}{2M}}e^{-1} = re^{\frac{r}{2M}-1} - 2Me^{\frac{r}{2M}-1}$$

The latter can be mathematically transformed as follows:

$$re^{\frac{r}{2M}-1} - 2Me^{\frac{r}{2M}-1} = r\left(\frac{r}{2M} - 1\right) - 2M\left(\frac{r}{2M} - 1\right) = \frac{r^2}{2M} - r - r + 2M = \frac{r^2}{2M} - 2r + 2M$$

This gives us the expression for radius r in the following form:

$$r = 2M\left[1 + W_0\left(\frac{x'^2 - t'^2}{e}\right)\right] = 2M\left[1 + W_0\left(\frac{r^2}{2M} - 2r + 2M\right)\right]$$

Let's write out the latter equation:

$$r = 2M + 2MW_0\left(\frac{r^2}{2M} - 2r + 2M\right) = 2M + W_0r^2 - 4MrW_0 + 4M^2W_0$$

As a result, we get:

$$r = 2M + W_0r^2 - 4MrW_0 + 4M^2W_0$$

Since the expressions in it are equal to:

$$W_0r^2 - 4MrW_0 = r^2W_0 - 2r^2W_0 = -r^2W_0$$

in which

$$4MrW_0 = 2\frac{2GM}{c^2}rW_0 = 2r^2W_0$$

we get radius r in the following form:

$$r = 2M - r^2W_0 + 4M^2W_0$$

In this we can in turn see that the following equation is valid:

$$r^2W_0 = 4M^2W_0 = \frac{4G^2M^2}{c^4}W_0$$

and this gives us the final form of radius r:

$$r = 2M$$

which together with constants:

$$r = \frac{2GM}{c^2}$$

Shows that it is actually the Schwarzschild radius r.

Since the equation used above was expressed as follows:

$$t'^2 - x'^2 = (2M - r)e^{\frac{r}{2M}} = 2Me^{\frac{r}{2M}} - re^{\frac{r}{2M}}$$

then we can present the coordinates accordingly:

$$t'^2 = 2Me^{\frac{r}{2M}}$$

$$x'^2 = re^{\frac{r}{2M}}$$

However, without the square, they would be expressed as follows:

$$t' = \frac{1}{2}\left(e^{\frac{v}{4M}} - e^{-\frac{w}{4M}}\right)$$

$$x' = \frac{1}{2}\left(e^{\frac{v}{4M}} + e^{-\frac{w}{4M}}\right)$$

Since such notations are also used in this metrical mathematics:

$$v'(v) = e^{\frac{v}{4M}}$$

$$w'(w) = -e^{-\frac{w}{4M}}$$

then the coordinates are also written like this:

$$t' = \frac{1}{2}(v' + w')$$

$$x' = \frac{1}{2}(v' - w')$$

In these equations, v and w are expressed as follows:

$$v = t + r + 2Mln(r - 2M)$$

$$w = t - r - 2Mln(r - 2M)$$

Since in mathematics, for example, the natural logarithm of $x = e^y$ in mathematics is: $lnx = y$, we can write the equation

$$v = t + r + 2Mln(r - 2M)$$

in the following form:

$$v = t + r + 2Me^{(r-2M)}$$

According to the logic of the previous analysis, we can transform the latter equation as follows:

$$v = t + r + 2M(r - 2M)$$

in which case we would get:

$$v = t + r + 2Mr - 4M^2 = t + r + \frac{2GM}{c^2}r - \frac{4G^2M^2}{c^4} = t + r + r^2 - r^2 = t + r$$

or $v = t + r$. The same logic would also apply in case such an equation:

$$w = t - r - 2Mln(r - 2M)$$

As a result, we get:

$$w = t - r - 2Mr + 4M^2 = t - r - \frac{2GM}{c^2}r + \frac{4G^2M^2}{c^4} = t - r - r^2 + r^2 = t - r$$

or $w = t - r$. This means that the equations:

$$v = t + r + 2Mln(r - 2M)$$

$$w = t - r - 2Mln(r - 2M)$$

can be expressed in the following form:

$$v = t + r$$

$$w = t - r$$

At this point, it is interesting to note that the resultant equation

$$w = t - r$$

coincides with the following relation:

$$l' = t' - r'$$

which will be derived later in this chapter. This shows that the expressions presented in this chapter are all mathematically related and also derivable, which gives credibility to the truth of the main statements of this chapter.

The time coordinate t' can be expressed as the following equation:

$$t' = \frac{1}{2}\left(e^{\frac{v}{4M}} - e^{-\frac{w}{4M}}\right)$$

Since above we obtained such relations through transformations:

$$v = t + r$$

$$w = t - r$$

then thus we can express the time coordinate as follows:

$$t' = \frac{1}{2}\left(e^{\frac{v}{4M}} - e^{-\frac{w}{4M}}\right) = \frac{1}{2}\left(\frac{t+r}{4M} + \frac{t-r}{4M}\right) = \frac{1}{2}\left(\frac{t}{4M} + \frac{r}{4M} + \frac{t}{4M} - \frac{r}{4M}\right) = \frac{t}{4M}$$

or

$$t' = \frac{t}{4M}$$

Let’s transform the latter equation:

$$\frac{t'}{t} = \frac{1}{4M} = \frac{1}{2}\frac{c^2}{2GM} = \frac{1}{2r} = \frac{1}{2l'}$$

Because gravitational time dilation applies in the theory of general relativity:

$$\frac{t'}{t} = \frac{1}{\sqrt{1-\frac{R}{r}}}$$

and gravitational contraction of length:

$$\frac{c}{c}\frac{t'}{t} = \frac{l}{l'} = \frac{1}{\sqrt{1-\frac{R}{r}}}$$

then, therefore, we can write the equation in the following form:

$$\frac{1}{2l'} = \frac{1}{\sqrt{1-\frac{R}{r}}}$$

Considering the previous relations, we can transform as follows:

$$\frac{1}{2} = \frac{l'}{\sqrt{1-\frac{R}{r}}} = l$$

We multiply both sides of the equation by two, as a result we get:

$$1 = \frac{2l'}{\sqrt{1-\frac{R}{r}}} = 2l$$

One side of the resulting equations overlaps with the gravitational length contraction equation:

$$\frac{l'}{\sqrt{1-\frac{R}{r}}} = l$$

or

$$l' = l\sqrt{1 - \frac{R}{r}}$$

However, it can also be converted mathematically in other ways. For example, the relationship presented above:

$$\frac{t'}{t} = \frac{1}{\sqrt{1 - \frac{R}{r}}} = \frac{1}{2r}$$

can be written in the following form:

$$\frac{t'}{t} = \frac{1}{l}$$

Knowing the above relations, we can transform the latter equation as follows:

$$\frac{l}{t} = \frac{1}{t'} = \frac{\sqrt{1 - \frac{R}{r}}}{t} = c$$

The resulting transformation equals the speed of light c:

$$\frac{\sqrt{1 - \frac{R}{r}}}{t} = \frac{l}{t} = c$$

since in the relation presented above:

$$\frac{t'}{t} = \frac{1}{\sqrt{1 - \frac{R}{r}}} = \frac{1}{2r} = \frac{1}{l}$$

there exists such an equation:

$$\sqrt{1 - \frac{R}{r}} = l$$

The latter equation needs to be proved separately here. For example, above, we were able to derive such a relation:

$$\frac{1}{2} = \frac{l'}{\sqrt{1 - \frac{R}{r}}} = l$$

Since we previously got $(2r)^2 = l^2$, from which it follows in turn:

$$\frac{1}{2} = \frac{r}{l}$$

then, therefore, we can write:

$$\frac{r}{l} = l$$

Consequently, the following equation:

$$l = \sqrt{1 - \frac{R}{r}}$$

can be written in the following form:

$$\frac{r}{l} = \sqrt{1 - \frac{R}{r}}$$

which actually coincides with the gravitational length contraction equation:

$$l' = l\sqrt{1 - \frac{R}{r}}$$

Similarly to the time coordinate t', we can convert the x' coordinate as follows:

$$x' = \frac{1}{2}\left(e^{\frac{v}{4M}} + e^{-\frac{w}{4M}}\right) = \frac{1}{2}\left(\frac{t+r}{4M} - \frac{t-r}{4M}\right) = \frac{1}{2}\left(\frac{t}{4M} + \frac{r}{4M} - \frac{t}{4M} + \frac{r}{4M}\right) = \frac{r}{4M}$$

In the obtained result, we need to change the notation for the sake of further analysis:

$$x' = l' = \frac{r}{4M} = \frac{l}{4M}$$

In the latter, we use constants, that is, we transfer the expressions to the SI system:

$$\frac{l'}{l} = \frac{1}{4M} = \frac{1}{2}\frac{c^2}{2GM} = \frac{1}{2r}$$

Similarly to the time coordinate t', we get the gravitational length contraction equation as a result:

$$\frac{l'}{l} = \sqrt{1 - \frac{R}{r}} = \frac{1}{2r}$$

or

$$l' = l\sqrt{1 - \frac{R}{r}}$$

which is already familiar to us from general relativity.

Above we saw that the difference in coordinates was expressed as follows:

$$t'^2 - x'^2 = l\left(1 - \frac{R}{r}\right) = \frac{l^2}{l} = l$$

or

$$t'^2 - x'^2 = l$$

The resulting relation can be proved as follows. For example, since the squares of the coordinates were all expressed in the same way:

$$t'^2 = 2Me^{\frac{r}{2M}} = 2M\left(\frac{r}{2M}\right) = r$$

$$x'^2 = re^{\frac{r}{2M}} = \frac{r^2}{2M} = r^2\frac{c^2}{2GM} = \frac{r^2}{r} = r$$

then, therefore, we can write:

$$r - r = l$$

The latter relation may in principle equal zero, but it may also indicate a more general expression:

$$x_1 - x_2 = l$$

This means that it can also be a difference in coordinates:

$$t' - x' = l'$$

and this proves the correctness of the above connection.

The metrics derived, presented and analysed above:

$$ds^2 = \frac{16M^2}{r}e^{-\frac{r}{2M}}(dt'^2 - dx'^2) - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

which contains (in turn the Kruskal-Szekeres metrics):

$$ds^2 = r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

can also be presented as follows in some cases:

$$ds^2 = -\frac{16M^2}{r}e^{-\frac{r}{2M}}dx'^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

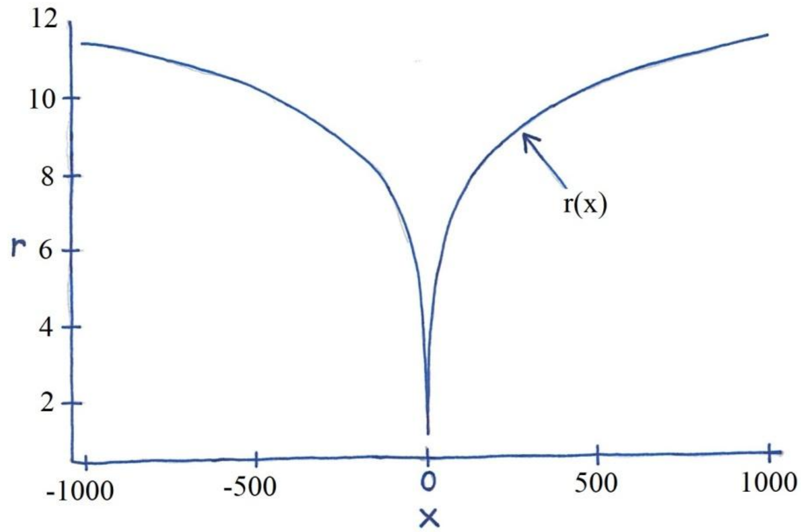
The square of the derivative of the x-coordinate in it can be expressed:

$$x'^2 = (r - 2M)e^{\frac{r}{2M}}$$

and radius according to the derivative of the x-coordinate:

$$r(x') = 2M\left[1 + W\left(\frac{x'^2}{2Me}\right)\right]$$

The figure that describes it is as follows:

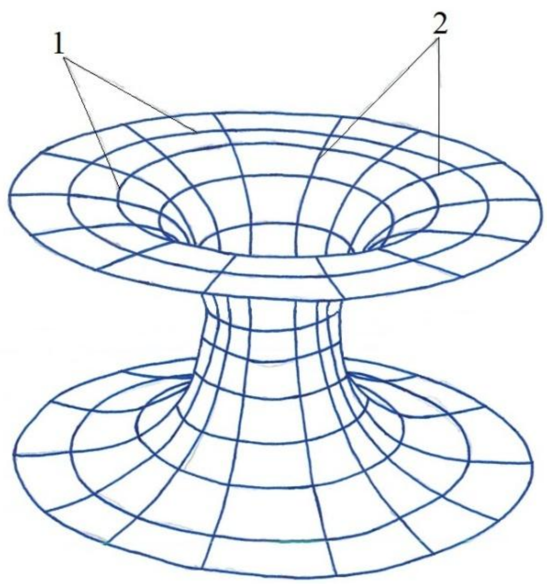


$$r(x) = 2M\left[1 + W\left(\frac{x^2}{2Me}\right)\right]$$

If $\theta = \frac{\pi}{2}$, then this metrics will have the following form:

$$ds^2 = -\frac{16M^2}{r}e^{-\frac{r}{2M}}dx'^2 - r^2 d\varphi^2$$

The resulting metric describes an Einstein-Rosen bridge or a Schwarzschild wormhole. We can better understand this metric if we consider a two-dimensional surface with a line element ds^2 transferred to a three-dimensional flat space. It looks like on the figure below:



1. $x' = constant$
2. $\varphi = constant$

W is the Lambert function. In mathematics, the Lambert W function, also called the "omega function" or "logarithm of the product", is a multivalued function, namely the branches of the inverse of the function f(w) = we^w, where w is any complex number and e^w is an exponential function.

For each integer k, there exists one branch, denoted $W_k(z)$. This is a complex-valued function with one complex argument. W_0 is known as the main branch. These functions have the following property. For example, if z and w were arbitrary complex numbers, then the relation

$$we^w = z$$

would be valid on the assumption that

$$w = W_k(z)$$

If only real numbers were involved, two branches would suffice: W_0 ja W_{-1}. For example, for real numbers x and y, the equation

$$ye^y = x$$

can be solved for y only if

$$x \geq -\frac{1}{e}$$

We can also get $y = W_0(x)$, if $x \geq 0$ and two values: $y = W_0(x)$ and $y = W_{-1}(x)$, if

$$-\frac{1}{e} \leq x < 0$$

The Lambert W relation cannot be expressed in terms of elementary functions.

In the latter metrics, the square of the derivative of the x-coordinate is expressed as follows:

$$x'^2 = (r-2M)e^{\frac{r}{2M}} = re^{\frac{r}{2M}} - 2Me^{\frac{r}{2M}}$$

Such an expression is unexpected, because if we compare it with the coordinate difference presented above:

$$t'^2 - x'^2 = (2M-r)e^{\frac{r}{2M}} = 2Me^{\frac{r}{2M}} - re^{\frac{r}{2M}}$$

then we see that the order of the equation is different and there is no time coordinate:

$$x'^2 - t'^2 = re^{\frac{r}{2M}} - 2Me^{\frac{r}{2M}} = (r-2M)e^{\frac{r}{2M}}$$

Nevertheless, these expressions are closely related. For example, if the latter expression would equal zero:

$$x'^2 - t'^2 = (r-2M)e^{\frac{r}{2M}} = 0$$

then the following equations should be valid:

$$x'^2 = t'^2$$

$$r = 2M$$

Consequently, we can write:

$$x'^2 - x'^2 = {x'}^2(1-1) = {x'}^2 * 0 = (r-2M)e^{\frac{r}{2M}} = 0$$

or

$${x'}^2 * 0 = 0 * e^{\frac{r}{2M}}$$

This is what gives us the reason to present such an equation:

$${x'}^2 = (r-2M)e^{\frac{r}{2M}}$$

which is used in this metrics. It turns out that this relation can be used in metrics even if the expression is no longer equal to zero.

Here, it is interesting to note that the above equation:

$$r = 2M$$

is actually valid in any case, because together with constants, that is, in the SI system, it manifests itself as follows:

$$r = \frac{2GM}{c^2}$$

This is the well-known Schwarzschild radius.

This form of expression for the radius r is also used in this metrics:

$$r(x') = 2M\left[1 + W\left(\frac{x'^2}{2Me}\right)\right]$$

which is different from the equation presented above:

$$r = 2M\left[1 + W_0\left(\frac{x'^2 - t'^2}{e}\right)\right]$$

The reason is that only the x-coordinate is taken into account:

$$x'^2 = re^{\frac{r}{2M}}$$

If we apply the technique used above:

$$x'^2 = re^{\frac{r}{2M}} = \frac{r^2}{2M}$$

then we see that we can perform the corresponding mathematical transformations:

$$\frac{r^2}{2M} \to \frac{x'^2}{2M}$$

1.9 A misinterpretation of the wormhole metric

The distance ds between two spatial points is described by the equation:

$$ds^2 = dx^2 + dy^2$$

or

$$ds = \sqrt{dx^2 + dy^2}$$

The latter equation can be converted into the following mathematical form:

$$ds = \sqrt{(dx)^2 + (dy)^2} = \sqrt{(dx)^2}\sqrt{\frac{((dx)^2 + (dy)^2)}{(dx)^2}} = \sqrt{1 + \left(\frac{dy}{dx}\right)^2}\,dx$$

If we integrate the derived relation

$$ds = \sqrt{1 + \left(\frac{dy}{dx}\right)^2}\,dx$$

we get the following very interesting result:

$$s = \int_0^{x'} \sqrt{1 + \left(\frac{dy}{dx}\right)^2}\, dx = \int_0^{x'} \sqrt{1 + (2x + i)^2}\, dx = \int_0^{x'} \sqrt{1 + 4x^2 + 4ix - 1}\, dx =$$

$$= \int_0^{x'} \sqrt{4x^2 + 4ix}\, dx$$

While integrating the equations, we took into account that

$$y = x^2 + ix$$

in which $i = \sqrt{-1}$. But we continue to integrate the equation further and we get the following result:

$$s \approx \int_0^{x'} \sqrt{4i}\sqrt{x}\, dx = \sqrt{4i}\,\frac{2}{3}\,x'^{\frac{y}{2}}$$

Next, we will try to calculate the distance c of the body m in an analogous way:

$$c = \sqrt{x'^2 + y'^2} = \sqrt{x'^2 + x'^4 + 2ix'^3 - x'^2} = \sqrt{x'^4 + 2ix'^3} = \sqrt{x'^2}\sqrt{x'^2 + 2ix'} = x'\sqrt{x'^2 + 2ix'}$$

and we get that the value of the distance c is approximately:

$$c \approx x'\sqrt{2ix'} = x'\sqrt{2i}\sqrt{x'}$$

In order to find out which distance is actually the shortest, we calculate the following limit value, i.e. the ratio of the distances s and c:

$$\lim_{x'\to 0} \frac{s}{c} = \lim_{x'\to 0} \frac{\sqrt{4i}\,\frac{2}{3}\,x'^{\frac{y}{2}}}{x'\sqrt{2ix'}} = \frac{\sqrt{4i}\,\frac{2}{3}\,x'^{\frac{y}{2}}}{x'\sqrt{2i}\sqrt{x'}} = \lim_{x'\to 0} \frac{2\sqrt{2}}{3}$$

Consequently, the relationship between s and c is expressed as follows:

$$\frac{s}{c} = \frac{2\sqrt{2}}{3} \approx 0{,}9428$$

and, therefore, the distance s is as much as 6% shorter than the distance c:

$$s \to 6\%$$

This physically means that the length of distance s is almost 6% shorter than distance c. Thus, the conventional understanding that the shortest path between two points in space is a straight line no longer applies to space transformations. In the case of space transformation, the distance is even shorter than a straight path. In the case of space transformation, also understood as the definition of space bending, distances become much closer to us.

At this point, it is important to note that the above analysis does not describe a tunnel in spacetime, or wormhole, but only that the distances are shortened when space(time) is transformed, or warped. In some publications or sources, the above analysis is considered a wormhole metric, but this definition is not actually correct. The above analysis only describes how distances become shorter in curved space.

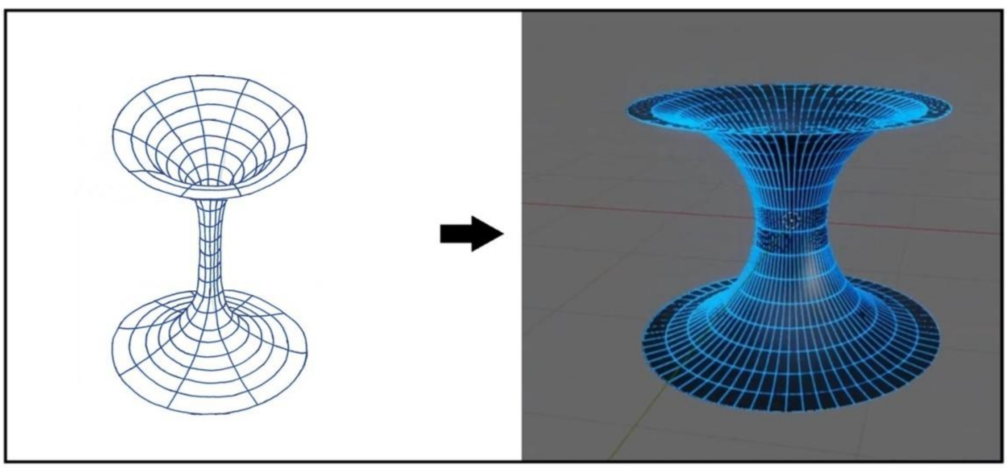
The physical distance s between two spatial points A and B becomes smaller, i.e. the space also transforms as it approaches the centre of the gravitational field. These points are located on a radius drawn from the centre 0:

$$s = \int_{r_1}^{r_2} F dr = \int_{r_1}^{r_2} \frac{dr}{\sqrt{1 - \frac{R}{r}}}$$

If you move away from the centre of the field, the distance between two spatial points of the field increases.

1.10 3D graphical representation of an tunnel in spacetime

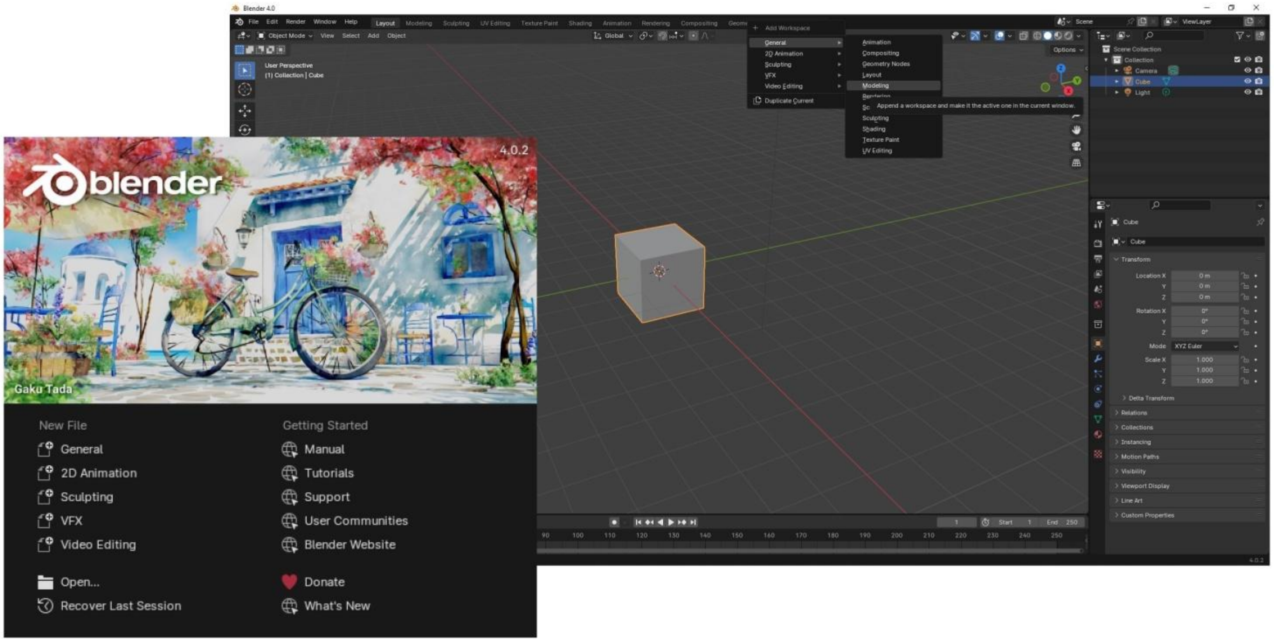
The tunnel in spacetime has been visualized in a computer program called Blender. Figure:

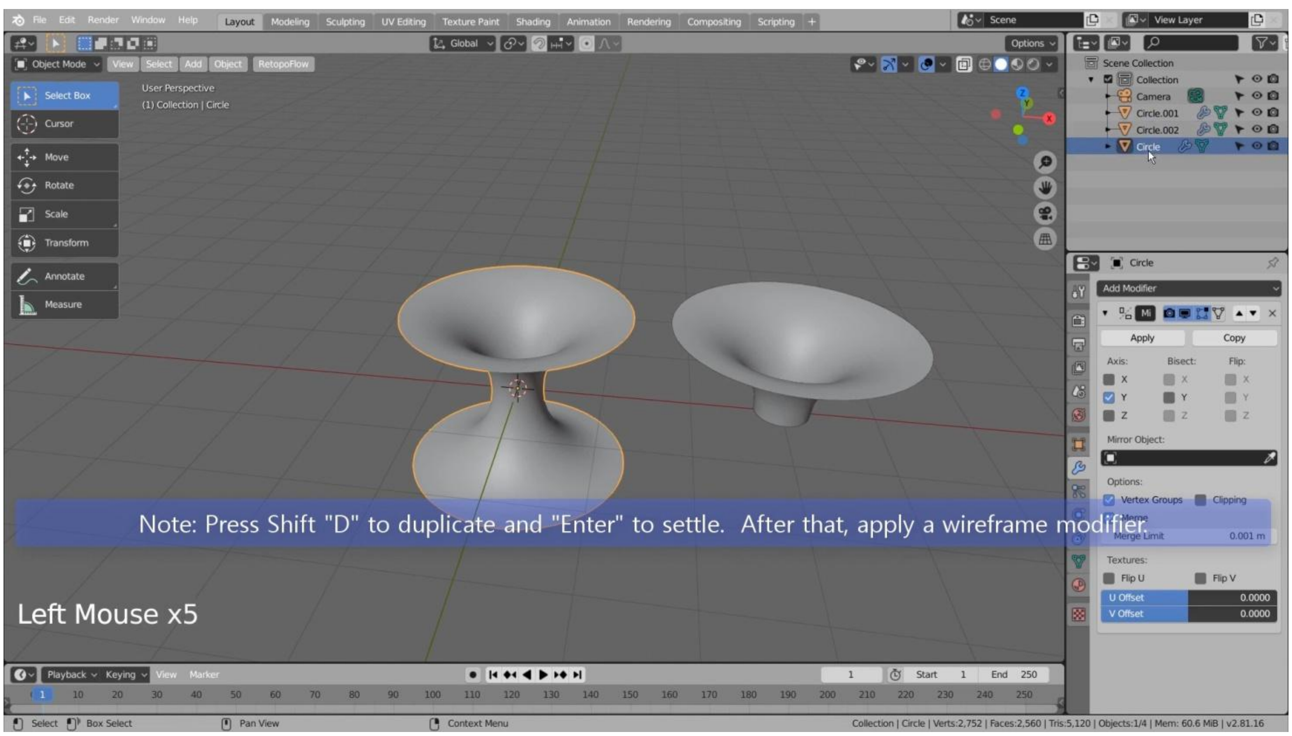


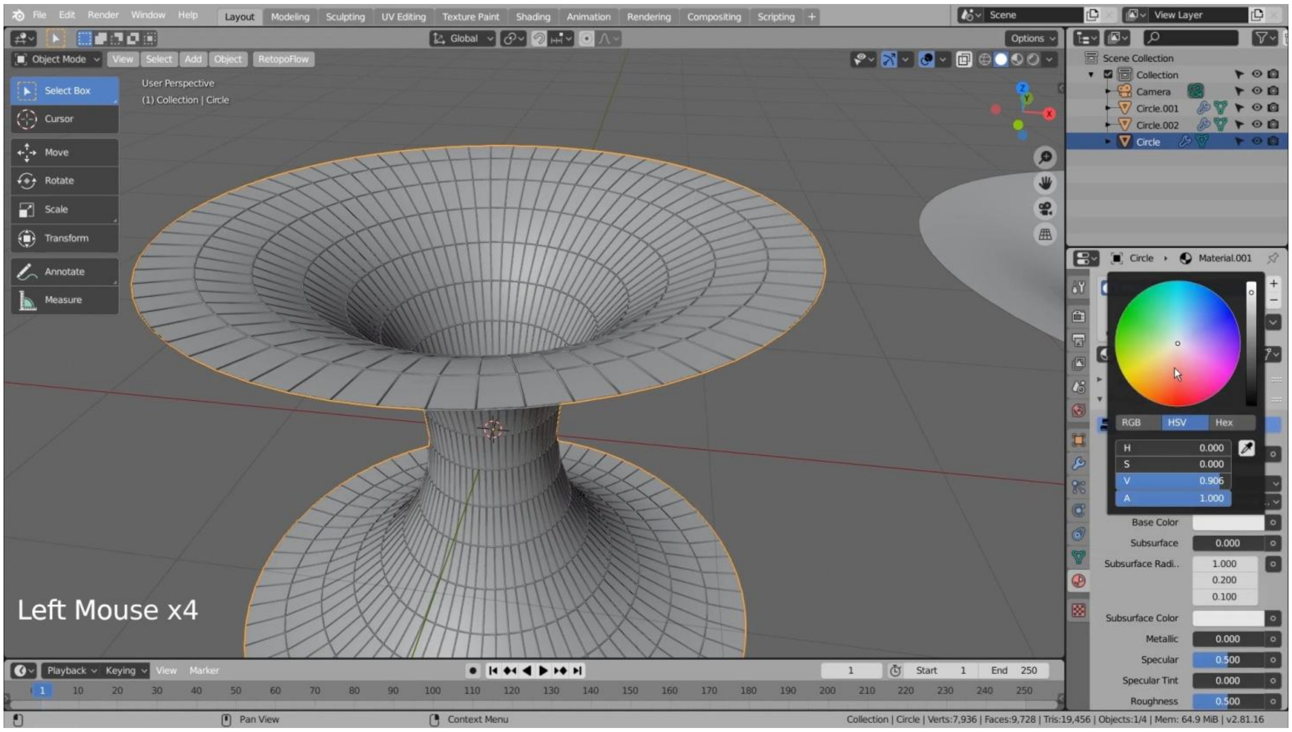
Blender is a computer program that can be used to create animated three-dimensional (or 3D) objects and environments. A computer program called 3D Blender can be downloaded and used for free at the Internet address: https://www.blender.org/. A three-dimensionally visualized, or animated, tunnel in spacetime creation video can be viewed and followed on the YouTube website (2):

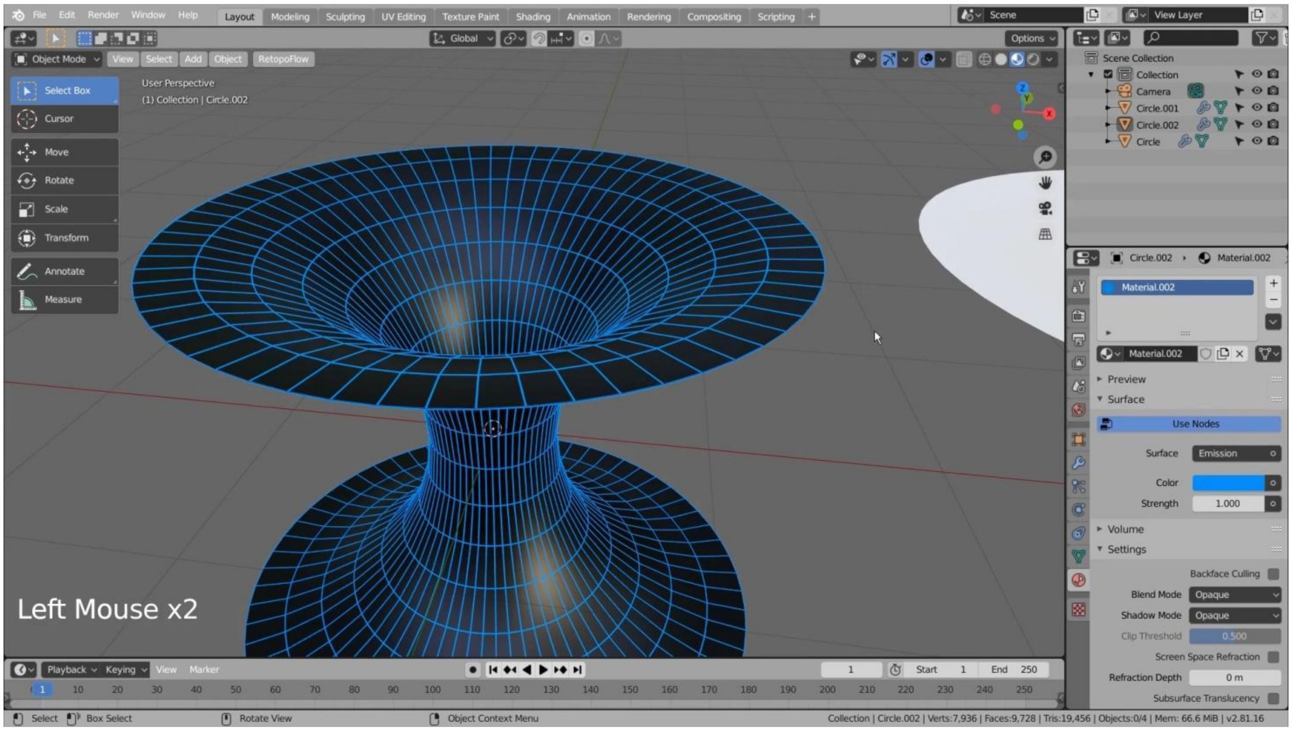
https://www.youtube.com/watch?v=zmK41NtJiE8

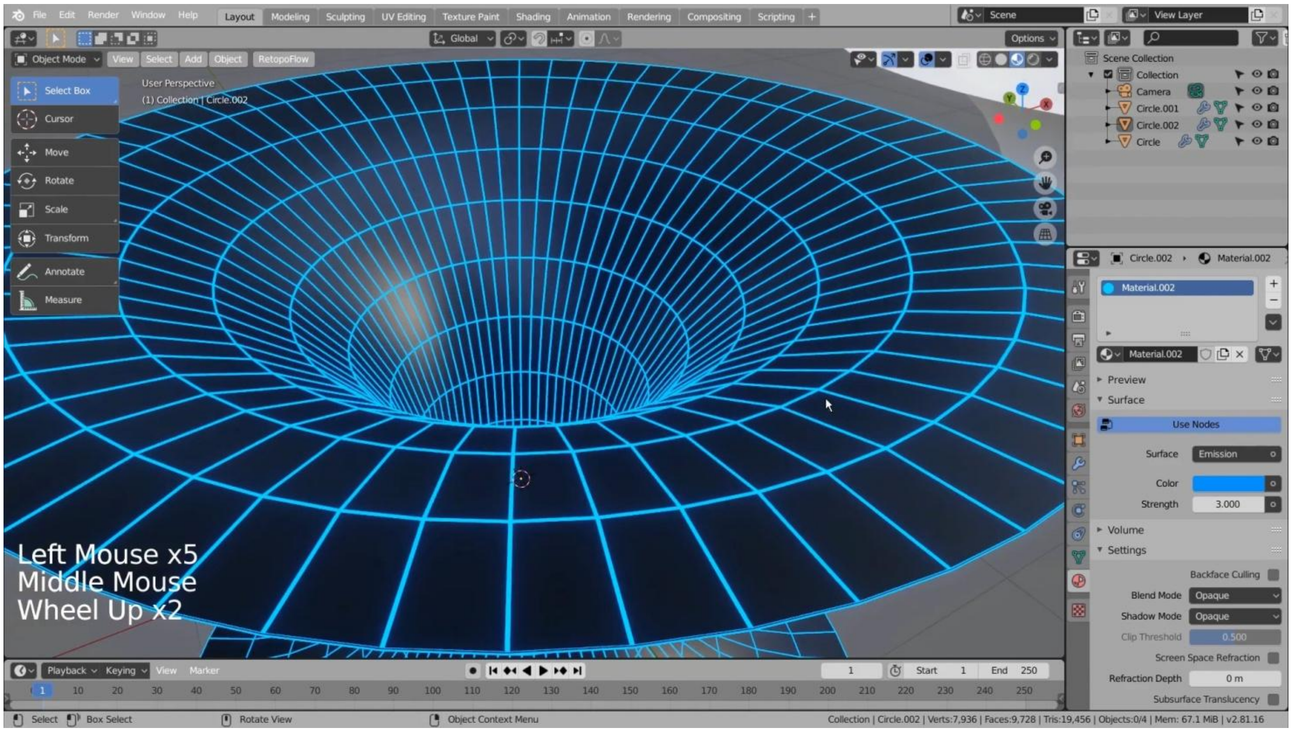
Below is a whole series of screenshots (pictures) from the previously mentioned educational video:

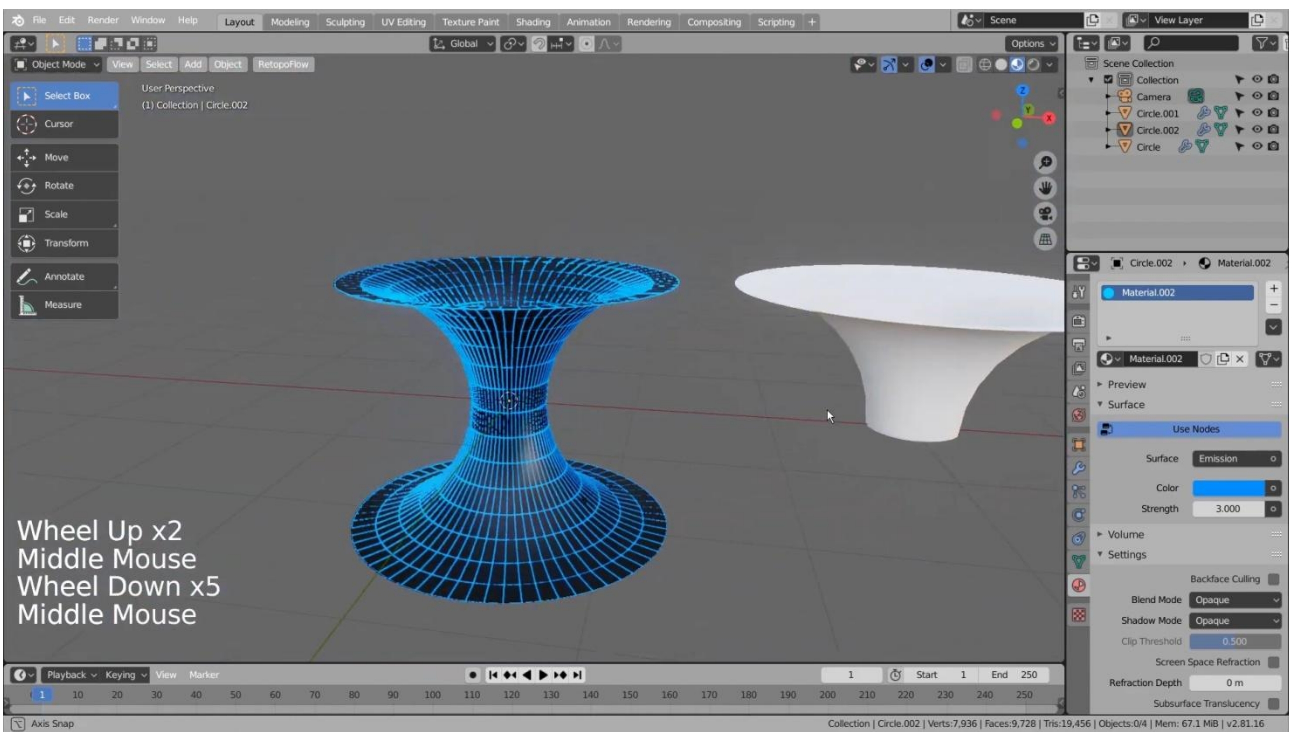

blender
4.0.2
Gaku Tada
New File
General
2D Animation
Sculpting
VFX
Video Editing
Open...
Recover Last Session
Getting Started
Manual
Tutorials
Support
User Communities
Blender Website
Donate
What's New

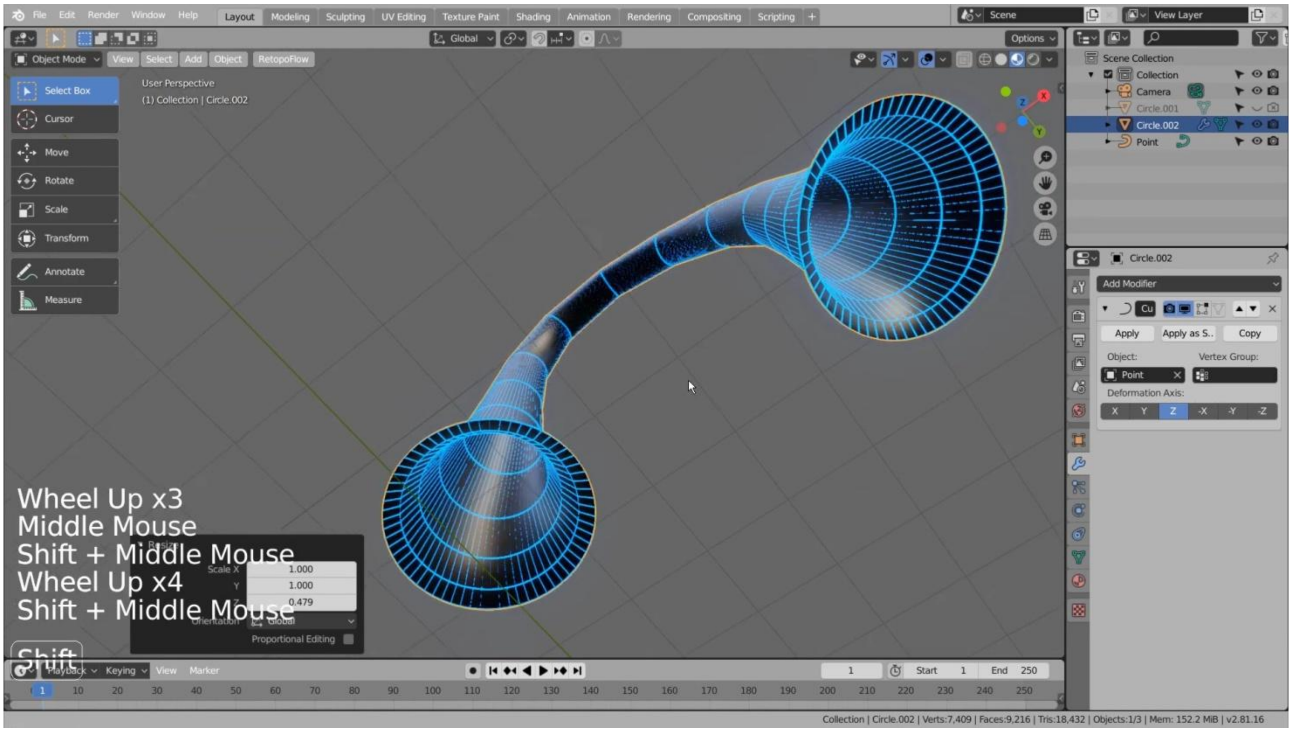

Note: Press Shift "D" to duplicate and "Enter" to settle. After that, apply a wireframe modifier.
Left Mouse x5

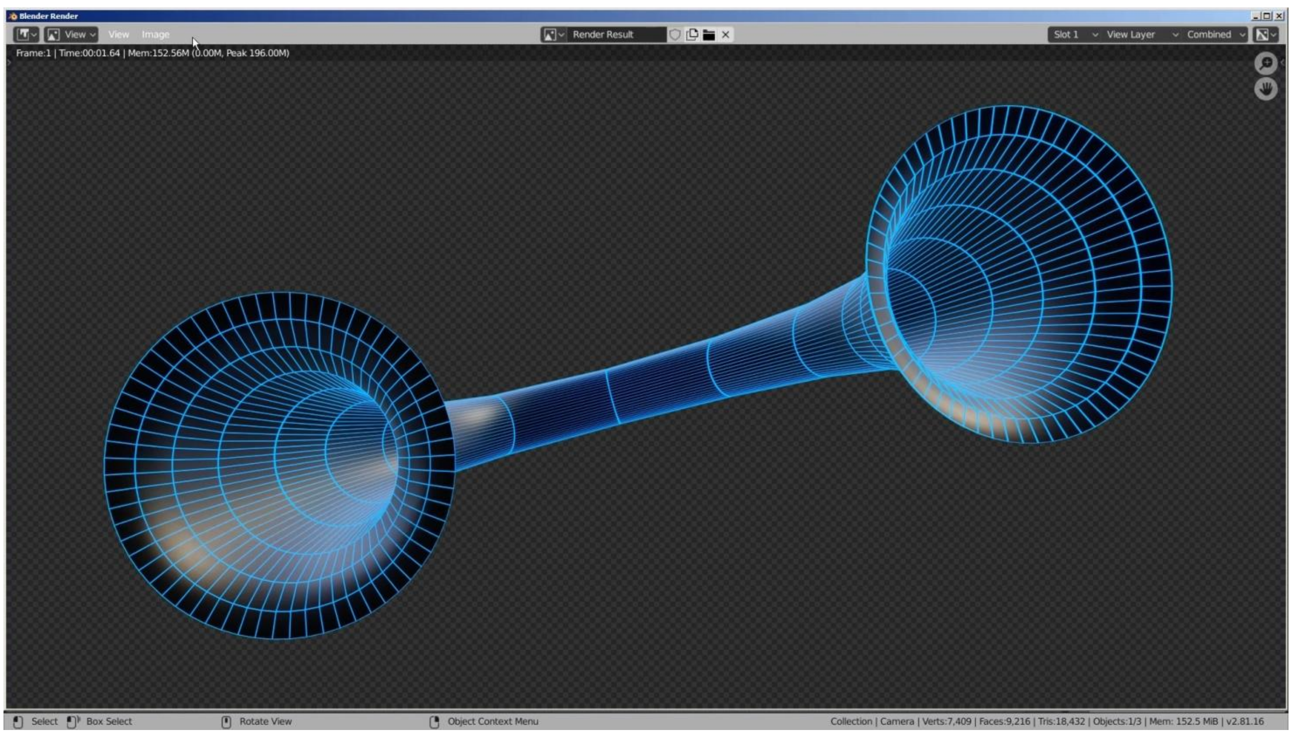

User Perspective
(1) Collection | Circle
Left Mouse x4


User Perspective
(1) Collection | Circle.002
Left Mouse x2

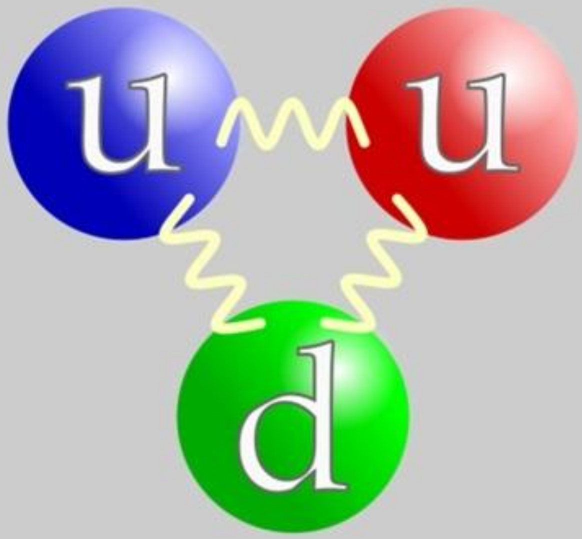

Left Mouse x5
Middle Mouse
Wheel Up x2


Wheel Up x2
Middle Mouse
Wheel Down x5
Middle Mouse


File Edit Render Window Help
Layout Modeling Sculpting UV Editing Texture Paint Shading Animation Rendering Compositing Scripting
Scene
View Layer
Object Mode View Select Add Object RetopoFlow
Global
Options
User Perspective
(1) Collection | Circle.002
Select Box
Cursor
Move
Rotate
Scale
Transform
Annotate
Measure
Scene Collection
Collection
Camera
Circle.001
Circle.002
Point
Add Modifier
Apply
Apply as S..
Copy
Object:
Vertex Group:
Point
Deformation Axis:
X Y Z -X -Y -Z
Wheel Up x3
Middle Mouse
Shift + Middle Mouse
Wheel Up x4
Shift + Middle Mouse
Shift
1.000
1.000
0.479
Proportional Editing
Playback Keying View Marker
Start 1
End 250
Collection | Circle.002 | Verts:7,409 | Faces:9,216 | Tris:18,432 | Objects:1/3 | Mem: 152.2 MiB | v2.81.16


Blender Render
View View Image
Render Result
Slot 1 View Layer Combined
Frame:1 | Time:00:01.64 | Mem:152.56M (0.00M, Peak 196.00M)
Select Box Select Rotate View Object Context Menu
Collection | Camera | Verts:7,409 | Faces:9,216 | Tris:18,432 | Objects:1/3 | Mem: 152.5 MiB | v2.81.16

The Mini-Standard Model of Particle Physics



2 The Mini-Standard Model of Particle Physics

2.1 Introduction

Deriving the values of the masses of elementary particles from the fundamental constants of physics is of decisive importance for understanding the derivation of the structure of matter (matter and field) from the physics of spacetime. Deriving the values of particle masses shows us how time and space determine what the nature and structure of matter in the universe must be. That is why it is necessary to learn about the physics theory of time travel and the mini-standard model. We will show this in the following.

The physical theory of time travel describes the spacetime of the universe as a physical system of ordinary space K and hyperspace K', in which ordinary space K moves with respect to hyperspace K' at the speed of light c. Consequently, the universe must also expand at the speed of light c. The quotient of the constants Planck length l and Planck time t known in physics gives us the speed of light c in vacuum:

$$v^2 = \frac{l^2}{t^2} = \frac{Ghc^5}{c^3Gh} = c^2$$

or

$$c = \frac{l}{t}$$

Therefore, the speed of light c can also be called the "Planck speed" c. Consequently, we have to take into account the quotient of the Planck length l and the Planck time t, i.e. the conclusions derived from the "Planck speed v". This simple connection also shows that the existence of Planck time and Planck length is a direct consequence of the physics of spacetime. The Planck time t and Planck length l are the basis for all other quantities that begin with the name "Planck" (e.g. Planck energy, Planck temperature, Planck density, Planck mass, Planck force, etc.). For example, the interrelationships between the elementary charge e, the Planck length l and the Planck mass m show that all fundamental constants of the universe are inextricably linked.

In the physics theory of time travel, the approach of the body's movement speed to the speed of light in vacuum is interpreted as an increase in the body's movement speed in ordinary space K, but in relation to hyperspace K', the body starts to stay still. From this it can be concluded that ordinary space K moves with speed c relative to hyperspace K´. For example, the physical system of ordinary space K and hyperspace K' is described by the general equation of time travel

$$ct + vt' = \sqrt{1 - \frac{v^2}{c^2}}\, t'c$$

from which it is possible to derive the time dilation equation, which is completely identical to the time transformation equation known from special relativity. For example, if vt´ = 0 in the previously mentioned general equation, i.e.

$$ct = \sqrt{1 - \frac{v^2}{c^2}}\, t'c$$

then we can mathematically transform as follows:

$$t = \sqrt{1 - \frac{v^2}{c^2}}\, t'$$

or

$$t' = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} t$$

in which the terms of the quotient

$$y = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

is called the y-factor in special relativity, or the kinematic factor, which shows the slowing down of time relative to an external observer. This mathematically shows the derivation of the phenomenon of time dilation from the previously derived physical system of hyperspace and normal space.

From the kinematic time dilation equation known from special relativity:

$$t` = \frac{t}{\sqrt{1 - \frac{v^2}{c^2}}}$$

it is possible, in turn, to "derive" the gravitational time dilation equation:

$$t` = \frac{t}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{t}{\sqrt{1 - \frac{2GM}{c^2 r}}} = \frac{t}{\sqrt{1 - \frac{R}{r}}}$$

in which there is Schwarzschild radius R that determines the size of the trapped surface in spacetime:

$$R = \frac{2GM}{c^2}$$

escape velocity of the planet v:

$$v^2 = \frac{2GM}{r}$$

and the expression for gravitational potential U:

$$\frac{GM}{r} = U$$

The gravitational potential is related to the Schwarzschild radius R as follows:

$$c^2 = \frac{2GM}{R} = 2U$$

which in turn gives us the greatest possible gravitational potential in the entire universe:

$$\frac{c^2}{2} = U$$

On the trapped surface in spacetime, the gravitational force and the electric force are equal to each other:

$$F_g = G\frac{m^2}{R_1^2} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{R_2^2} = F_{el}$$

which also means that the electric force is equal to the Planck force:

$$F_p = \frac{c^4}{G} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{R^2}$$

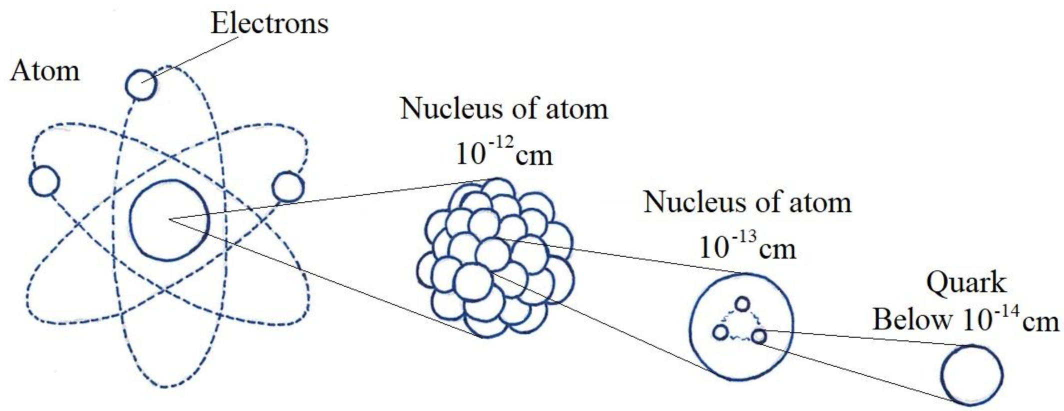
From the latter, for example, the value of mass of a proton m is derived:

$$m_p = \sqrt{\frac{ke^2}{c^3\pi}}$$

The previous overview analysis shows the derivation of the structure of matter (matter and field) from the physics of spacetime. This shows how time and space determine the nature and structure of matter in the universe.

2.2 Particles and their masses

Electrons, nucleus of atom and quark, figure:



From the electric charge e of a proton:

$$\frac{2}{3}e + \frac{2}{3}e - \frac{1}{3}e = +e = 1{,}602 * 10^{-19}\ C$$

we can derive the mass of a proton and through it the mass of a neutron. It is known from the "hydrogen atom" that two elementary electric charges with a distance r:

$$r = 5{,}3 * 10^{-11}\ m$$

affect each other with an electric force F:

$$F = 8{,}2 * 10^{-8}\ N$$

At this distance, the gravitational force F between the two protons would be:

$$F = 6{,}6480 * 10^{-44}\ N$$

Consequently, the electric force is greater than the gravitational force

$$\frac{F_{el}}{F_g} = 1{,}233 * 10^{36}$$

times. However, in the following we derive the value of the mass of a proton. We can directly derive the mass of a proton from the formula derived above:

$$R = \sqrt{\frac{e^2 G}{4\pi\varepsilon_0 c^4}} = 1{,}3807 * 10^{-36}\ m$$

where e is the electric charge of a proton. The latter equation shows the radius R of a trapped surface in spacetime, which is generated by the electric charge e of a proton. The given formula is directly derived from the equation for Schwarzschild radius R:

$$R = \frac{GM}{c^2} = \frac{G}{c^2}\frac{E}{c^2} = \frac{GE}{c^4} = \frac{G}{c^4}E = \frac{G}{c^4}k\frac{q^2}{r}$$

or

$$R = \frac{G}{c^4}k\frac{e^2}{R}$$

The "definition" of the Planck force F_p can be become evident from the latter:

$$F_p = \frac{Gm^2}{r^2} = \frac{Gm^2}{\left(\frac{Gm}{c^2}\right)^2} = \frac{Gm^2c^4}{G^2m^2} = \frac{c^4}{G} =$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{e^2}{R^2} = 1{,}2 * 10^{44}\ N$$

or

$$F_p = \frac{c^4}{G} = \frac{E}{l_p} = \frac{mc^2}{l_p} = \frac{hf}{l_p} = \frac{h}{t}\frac{1}{l_p} = \frac{h}{l_p}\frac{c}{l_p} = \frac{hc}{l_p^2}$$

from which, in turn, we get

$$G_p = \frac{l_p^2 c^3}{h}$$

According to this, gravitational force and the electric force are equal to each other on the trapped surface of spacetime:

$$F_g = G\frac{m^2}{R_1^2} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{R_2^2} = F_{el}$$

in which the Schwarzschild radius is present:

$$R_1 = \frac{Gm}{c^2}$$

as well as the „Nordström radius“:

$$R_2 = \sqrt{\frac{e^2 G}{4\pi\varepsilon_0 c^4}}$$

Since in the equation for Planck force:

$$F_p = \frac{c^4}{G} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{R^2}$$

there exist c^4 and G, then according to the relation of the square of the rest energy $E^2 = m^2c^4$ and Newton's gravitational force $F = \frac{Gm^2}{r^2}$, we can mathematically transform the equation as follows:

$$F_p = \frac{c^4}{G} = \frac{E^2}{m^2}\frac{m^2}{Fr^2}$$

As a result, we get the equations for electric force and gravitational force:

$$F^2 = \frac{E^2}{r^2} = F^2$$

or $F = F$. However, in the equation derived above

$$\frac{c^4}{G} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{R^2}$$

we will perform some simple mathematical transformations for further analysis:

$$\frac{c^4}{G} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{R^2} \quad \rightarrow \quad \frac{c^3}{G}\pi = \frac{1}{4\varepsilon_0 c}\frac{e^2}{R^2} =$$

$$= \frac{c^4}{G}\frac{\pi}{c} = F_p\frac{\pi}{c} = 1{,}27106 * 10^{36}$$

The resulting equation

$$\frac{c^3}{G}\pi = \frac{1}{4\varepsilon_0 c}\frac{e^2}{R^2}$$

actually shows the "ratio" between the electric force and the gravitational force, which in turn can be used to obtain the value of the mass of a proton. We demonstrate this with the following simple analysis. For example, the latter equation mathematically transforms into:

$$\frac{c^2}{G} = \frac{1}{4\pi\varepsilon_0 c^2}\frac{e^2}{R^2}$$

If we consider the rest energy relation from special relativity:

$$E = mc^2$$

and with the definition of gravitational force from Newtonian mechanics:

$$F_g = \frac{Gm}{r^2}$$

we get the equation in the following form:

$$\frac{c^2}{G} = \frac{E}{m}\frac{m}{F_g r^2}$$

or

$$\frac{c^2}{G} = \frac{E}{F_g r^2} = \frac{1}{F_g r}\frac{1}{r}E = \frac{1}{F_g r}\frac{1}{r}\left(k\frac{q^2}{r}\right) =$$

$$= \frac{1}{F_g}\frac{1}{r}k\frac{q^2}{r^2} = \frac{F_{el}}{F_g}\frac{1}{r}$$

The resulting simple relation:

$$\frac{c^2}{G} = \frac{F_{el}}{F_g}\frac{1}{r}$$

can also be expressed as follows:

$$\frac{c^2}{G} = \frac{c^4}{G}\frac{1}{c^2} = \frac{F_p}{c^2} = \frac{F_{el}}{F_g}\frac{1}{r}$$

which shows that it actually equals one:

$$\frac{F_p r}{c^2} = \frac{U}{c^2} = \frac{c^2}{c^2} = 1 = \frac{F_{el}}{F_g}$$

This follows directly from the fact that the gravitational potential U on the trapped surface of spacetime is "limited" to the maximum possible value in the universe:

$$t` = \frac{t}{\sqrt{1-\frac{R}{r}}} = \frac{t}{\sqrt{1-\frac{GM}{c^2 r}}} = \frac{t}{\sqrt{1-\frac{U}{c^2}}} = \infty$$

in which:

$$U = c^2 = G\frac{m_p}{l_p} = U_p$$

On the trapped surface of spacetime, the electric force and the gravitational force are equal. However, in the following we disclose and transform the previously derived equation:

$$\frac{c^2}{G} = \frac{F_{el}}{F_g}\frac{1}{r} = \frac{F_{el}}{F_g}\frac{1}{ct}$$

in three different possible ways:

$$\frac{c^3}{G} = \frac{F_{el}}{F_g}\frac{1}{t}$$

and

$$\frac{c^3}{G} = \frac{1}{4\pi\varepsilon_0 c}\frac{e^2}{R^2} = \frac{E}{cR} = \frac{p}{R} = \frac{mc}{R} = \frac{m}{t}$$

and

$$\frac{c^3}{G} = \frac{1}{4\pi\varepsilon_0 c}\frac{e^2}{R^2} = \frac{E}{cR} = \frac{h}{ct2\pi R} =$$

$$= \frac{h}{2\pi r}\frac{1}{R} = \frac{h}{\pi R}\frac{1}{R} = \frac{mc}{\pi R} = \frac{m}{\pi t}$$

From the last three equations we can create a set of equations:

$$\begin{cases} \dfrac{c^3}{G} = \dfrac{F_{el}}{F_g}\dfrac{1}{t} \\ \dfrac{c^3}{G} = \dfrac{m}{t} \\ \dfrac{c^3}{G} = \dfrac{m}{\pi t} \end{cases} \qquad \frac{c^3}{G} = \begin{cases} \dfrac{F_{el}}{F_g}\dfrac{1}{t} \\ \dfrac{m}{t} \\ \dfrac{m}{\pi t} \end{cases}$$

From these sets of equations we get the following equations:

$$\frac{F_{el}}{F_g} = \frac{c^3}{G}t = \frac{m}{\pi}$$

which shows the "relationship" between the electric force and the gravitational force not on the trapped surface of spacetime:

$$\frac{c^3}{G}t\pi = m = \frac{c^3}{G}t = \frac{F_{el}}{F_g}$$

whereas the time t actually "reduces" nicely out of the equation:

$$\frac{c^3}{G}\pi = \frac{F_{el}}{F_g}$$

This means that if the following relation holds true:

$$\frac{c^3}{G}t\pi = \frac{F_{el}}{F_g}$$

in which $\frac{F_{el}}{F_g} = \frac{c^3}{G}t$, then the following equations “must” also hold:

$$\frac{c^3}{G}\pi = \frac{F_{el}}{F_g}$$

in which $\frac{F_{el}}{F_g} = \frac{c^3}{G}$. In this case, we got a multiplier, or a constant:

$$\frac{F_{el}}{F_g} = \frac{c^3}{G}\pi = 1{,}27106 * 10^{36} \neq 1$$

which actually shows that the electric force is many times greater than the gravitational force not on the trapped surface of spacetime:

$$\frac{kq^2}{Gm^2} = \frac{c^3}{G}\pi$$

However, on the trapped surface of spacetime, it is:

$$\frac{c}{\pi}\frac{kq^2}{Gm^2} = \frac{c^4}{G} = F_p$$

From such a relationship, we get the value of the mass m of a proton:

$$m = \sqrt{\frac{ke^2}{c^3\pi}} = 1{,}65 * 10^{-27}\ kg$$

since we had two protons which must have the same electric charge and also the same mass. Compared to the more precise/actual value of the mass of a proton ($m = 1{,}673 * 10^{-27}\ kg$), the previous result is excellent.

Deriving the value of the proton mass m from the fundamental constants of physics is of decisive importance for understanding the derivation of the structure of matter from the spacetime continuum. The mathematical analysis presented above must be supplemented with some important remarks. Deriving the value of the mass of a proton shows how mathematics and physics are still different sciences, even though the two are closely intertwined. In mathematics we have to take into account mathematical regularities, but in physics we also have to take into account physical regularities, which are not taken into account in mathematics. We will show this in the following. For example, on the trapped surface in spacetime, the gravitational force and the electric force are equal to each other:

$$F_g = G\frac{m^2}{R_1^2} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{R_2^2} = F_{el}$$

which also means that the electric force is equal to the Planck force:

$$F_p = \frac{c^4}{G} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{R^2}$$

From the latter we get the following expression:

$$\frac{c^2}{G} = \frac{1}{4\pi\varepsilon_0 c^2}\frac{e^2}{R^2}$$

Considering the rest energy equation $E = mc^2$ and the gravitational force equation $F_g = \frac{Gm}{r^2}$, we get the following result:

$$\frac{c^2}{G} = \frac{E}{m}\frac{m}{F_g r^2}$$

We can transform the latter as follows:

$$\frac{c^2}{G} = \frac{E}{F_g r^2} = \frac{1}{F_g r}\frac{1}{r}E = \frac{1}{F_g r}\frac{1}{r}\left(k\frac{q^2}{r}\right) = \frac{1}{F_g}\frac{1}{r}k\frac{q^2}{r^2} = \frac{F_{el}}{F_g}\frac{1}{r} = \frac{F_{el}}{F_g}\frac{1}{ct}$$

where F_{el} is electric force and F_g is gravitational force. By considering the previous relations, we can express the values of $\frac{c^3}{G}$ as follows:

$$\frac{c^3}{G} = \frac{F_{el}}{F_g}\frac{1}{t}$$

and

$$\frac{c^3}{G} = \frac{1}{4\pi\varepsilon_0 c}\frac{e^2}{R^2} = \frac{E}{cR} = \frac{p}{R} = \frac{mc}{R} = \frac{m}{t}$$

and

$$\frac{c^3}{G} = \frac{1}{4\pi\varepsilon_0 c}\frac{e^2}{R^2} = \frac{E}{cR} = \frac{h}{ct2\pi R} = \frac{h}{2\pi r}\frac{1}{R} = \frac{h}{\pi R}\frac{1}{R} = \frac{mc}{\pi R} = \frac{m}{\pi t}$$

In the latter, we can take into account that $2r = R = l$. As a result, we get:

$$\frac{F_{el}}{F_g} = \frac{c^3}{G}t = \frac{m}{\pi}$$

Based on the previous relations, we can write:

$$\frac{c^3}{G}t\pi = m = \frac{c^3}{G}t = \frac{F_{el}}{F_g}$$

from which it can be seen that:

$$\frac{c^3}{G}t\pi = \frac{c^3}{G}t$$

This is a very important relation. We see that time t is cancelled out from the equation:

$$\frac{c^3}{G}\pi = \frac{c^3}{G}$$

Based on the above relations, this equation must also equal the following:

$$\frac{F_{el}}{F_g}\frac{1}{t}\pi = \frac{F_{el}}{F_g}\frac{1}{t}$$

Time t is cancelled out in this as well:

$$\frac{F_{el}}{F_g}\pi = \frac{F_{el}}{F_g}$$

Since the times t are subtracted in each equation, we can write:

$$\frac{c^3}{G}\pi = \frac{F_{el}}{F_g}$$

From such an expression we got the value of the mass of a proton:

$$m = \sqrt{\frac{ke^2}{c^3\pi}} = 1{,}65 * 10^{-27}\ kg$$

which almost coincides with the actual value: $m = 1{,}673 * 10^{-27}\ kg$. We got this result when time t was removed from the equations. However, if we leave the time t in the equations:

$$\frac{c^3}{G}\pi = \frac{F_{el}}{F_g}\frac{1}{t}$$

then this would give equation for the mass of a proton in the following form:

$$m = \sqrt{\frac{ke^2}{c^3\pi}\frac{1}{t}} = 1{,}65 * 10^{-27}\ kg$$

It also follows that the time t must be equal to one or removed from the equations in order to obtain the value of the mass of a proton. We will show this briefly as follows. We can write the latter equation in the following form:

$$m = \sqrt{\frac{ke^2}{c^3\pi}}\frac{1}{\sqrt{t}}$$

In fact, the equation for the mass m of a proton already exists in it:

$$m = m\frac{1}{\sqrt{t}}$$

We square both sides of the equation:

$$m^2 = m^2\frac{1}{t}$$

and divide both sides of the equation by mass m:

$$m = \frac{m}{t}$$

From the resulting equation, we see that it is equal to the expressions derived above:

$$\frac{c^3}{G} = \frac{1}{4\pi\varepsilon_0 c}\frac{e^2}{R^2} = \frac{E}{cR} = \frac{p}{R} = \frac{mc}{R} = \frac{m}{t}$$

and

$$\frac{c^3}{G} = \frac{F_{el}}{F_g}\frac{1}{t}$$

This means that we get the following equations as a result:

$$m = \frac{m_p}{t} = \frac{c^3}{G} = \frac{F_{el}}{F_g}\frac{1}{t}$$

but only if the following expression holds:

$$m_p = \sqrt{\frac{ke^2}{c^3\pi}}$$

This is the equation showing the value of the mass of a proton, which we derived above. Such a derivation shows more strictly the derivation of such a relation from the fundamental constants and also its validity.

From the mass and the electric charge of a proton and a quark structure of a neutron

$$\frac{2}{3}e - \frac{1}{3}e - \frac{1}{3}e = 0$$

it follows that the mass of a neutron must be "almost" equal to the mass of a proton, more precisely:

$$m = 1{,}675 * 10^{-27}\ kg$$

After all, the neutral electric charge of a neutron "consists" of three elementary charges e:

$$e = 1{,}602 * 10^{-19}\ C$$

which are all also fractional values. Since a neutron decays into a proton and an electron (and also an antielectron neutrino)

$$n^0 \to p^+ + e^- + \bar{\nu}$$

then, in principle, it can also be concluded from this that, according to the law of conservation of energy, a neutron must have a "slightly" larger mass than a proton, and the masses of an electron and an anti-electron neutrino would in this case be the "difference" between the masses of a neutron and a proton. The mass of an antielectron neutrino is so small that it can be neglected in this case:

$$n^0 \to p^+ + e^-$$

An electron is absorbed in the reaction:

$$p + e^- \to n + v$$

since the electron is interacting with the proton. However, such an interaction could not produce the following reaction:

$$n \to p + e^- + \tilde{v}$$

because at the beginning of such a reaction there is no electron at all. According to quantum field theory, particles correspond to a field in vacuum that exists everywhere and always. The field in vacuum is in its minimum energy state in the absence of real particles. According to this understanding, there exists, at the beginning of the reaction:

$$n \to p + e^- + \tilde{v}$$

A neutron field in a single particle state with energy:

$$E = mc^2$$

however, other fields are in minimum state or vacuum state. After that, the neutron field itself went into vacuum state, in which the energy of the neutron field was transferred to proton, electron and antineutrino fields. All three of them went into single-particle state. Since there is an interaction between all fields from the beginning, such a reaction could take place. Since every particle has its own antiparticle, it would be more correct to say that there is an electron-positron field rather than just an electron field.

However, we can "derive" the mass of an electron from the formula for the mass of a proton:

$$\frac{F_{el}}{F_g} = \frac{c^3}{G}\pi$$

In order to do this, we apply to the equation derived above:

$$\frac{c^3}{G}\pi = (F_p)\frac{\pi}{c} = \left(\frac{1}{4\pi\varepsilon_0}\frac{e^2}{R^2}\right)\frac{\pi}{\sqrt{c}\sqrt{c}}$$

the following mathematical transformations:

$$\frac{c^3}{G}\frac{\sqrt{c}}{\pi} = \left(\frac{1}{4\pi\varepsilon_0}\frac{e^2}{R^2}\right)\frac{1}{\pi\sqrt{c}}$$

According to this, we get the, “instead” of the formula:

$$\frac{kq^2}{Gm^2} = \frac{c^3}{G}\pi$$

a new expression:

$$\frac{kq^2}{Gm^2} = \frac{c^3}{G}\frac{\sqrt{c}}{\pi}$$

or

$$\frac{c\pi}{\sqrt{c}}\frac{kq^2}{Gm^2} = \frac{c^4}{G} = F_p$$

which gives us the value of the mass of an electron:

$$\frac{ke^2\pi}{c^3\sqrt{c}m_p} = m_e = 9{,}3 * 10^{-31}\ kg$$

In the latter, e is the elementary charge and m_p is the mass of a proton. Compared to the more accurate/actual mass value of an electron ($m = 9{,}109 * 10^{-31}\ kg$) , the previous result is excellent. The physical content of the above is that the electric charges of a proton and an electron with a distance

$$r = 5{,}3 * 10^{-11}\ m$$

affect each other in the hydrogen atom with an electric force:

$$F = 8{,}2 * 10^{-8}\ N$$

However, the gravitational force between a proton and an electron is only:

$$F = 3{,}7 * 10^{-47}\ N$$

According to this, the electric force is greater than the gravitational force

$$\frac{F_{el}}{F_g} = 2{,}2162 * 10^{39}$$

times.

Between two electrons that are spaced apart by a distance:

$$r = 5{,}3 * 10^{-11}\ m$$

there also exists an electric force:

$$F = 8{,}2 * 10^{-8}\ N$$

In this case, the gravitational force between two electrons is:

$$F = 1{,}97022 * 10^{-50}\ N$$

Therefore, in case of two electrons, the electric force is greater than the gravitational force

$$\frac{F_{el}}{F_g} = 4{,}16197 * 10^{42}$$

times. This is a very big difference. From the interaction between a proton and an electron in the hydrogen atom, we were able to derive the value of an electron's mass:

$$\frac{ke^2\pi}{c^3\sqrt{c}m_p} = m_e = 9{,}3 * 10^{-31}\ kg$$

in which the mass of a proton was also expressed:

$$m_p = \sqrt{\frac{ke^2}{c^3\pi}} = 1{,}65 * 10^{-27}\ kg$$

By applying these two different equations

$$m_e = \frac{ke^2\pi}{c^3\sqrt{c}}\frac{1}{m_p} = \frac{ke^2\pi}{c^3\sqrt{c}}\frac{1}{\sqrt{\frac{ke^2}{c^3\pi}}} = \frac{ke^2\pi}{c^3\sqrt{c}\sqrt{\frac{ke^2}{c^3\pi}}}$$

or

$${m_e}^2 = \left(\frac{ke^2\pi}{c^3\sqrt{c}}\right)^2 \frac{c^3\pi}{ke^2} = \frac{\pi^3 ke^2}{c^4}$$

we can "derive" the squared value of the mass of an electron:

$$m_e^2 = \frac{\pi^3 ke^2}{c^4}$$

in which gravitational force and electric force exist between two electrons. In this case, we get the value of the mass of an electron:

$$m_e^2 = \frac{\pi^3 ke^2}{c^4} \quad \rightarrow$$

$$\rightarrow \ m_e = \sqrt{\frac{\pi^3 ke^2}{c^4}} = 9{,}3958 * 10^{-31}\ kg$$

which is “also” equal to the value we got above:

$$\frac{ke^2\pi}{c^3\sqrt{c}m_p} = m_e = 9{,}3754 * 10^{-31}\ kg$$

However, the more accurate/actual value of the mass of an electron is $m = 9{,}109 * 10^{-31}\ kg$.

In the case of proton-electron interaction, the electric force was greater than the gravitational force

$$\frac{c^3}{G}\frac{\sqrt{c}}{\pi} = \left(\frac{1}{4\pi\varepsilon_0}\frac{e^2}{R^2}\right)\frac{1}{\pi\sqrt{c}}$$

times. The latter equation or

$$\frac{c^4}{G}\frac{1}{\pi} = \frac{1}{4\pi^2\varepsilon_0}\frac{e^2}{R^2}$$

can be mathematically transformed

$$\frac{c^4}{G}\frac{\pi^2}{\pi} = F_p\frac{\pi^2}{\pi}$$

to the following form

$$\frac{c^4}{G}\frac{1}{\pi^3} = F_p\frac{1}{\pi^3}$$

which can also be clearly seen from the last derived expression for the mass of an electron:

$$m_e^2 = \frac{\pi^3 ke^2}{c^4}$$

For example, the latter equation shows the ratio of electric force and gravitational force between two electrons:

$$\frac{c^4}{G}\frac{1}{\pi^3} = \frac{ke^2}{Gm_e^2} \approx 4{,}16197 * 10^{42}$$

From the latter simple equation:

$$\frac{c^4}{G}\frac{1}{\pi^3} = F_p\frac{1}{\pi^3}$$

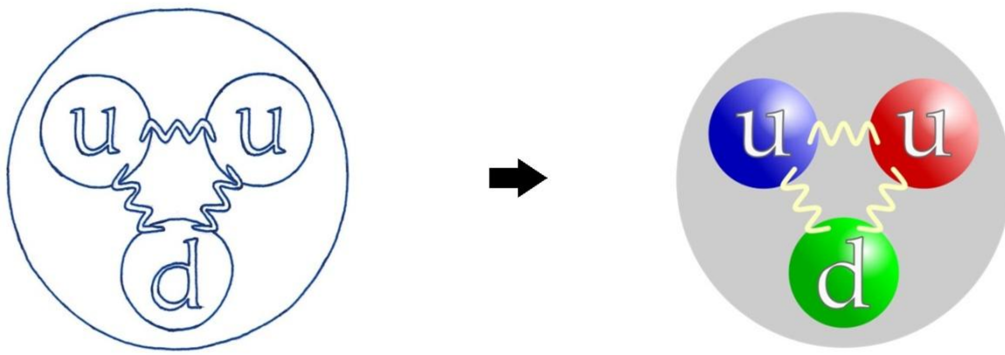
it is actually possible to mathematically derive the mass of a proton mass directly from equation:

$$m_p = \sqrt{\frac{ke^2}{c^3\pi}}$$

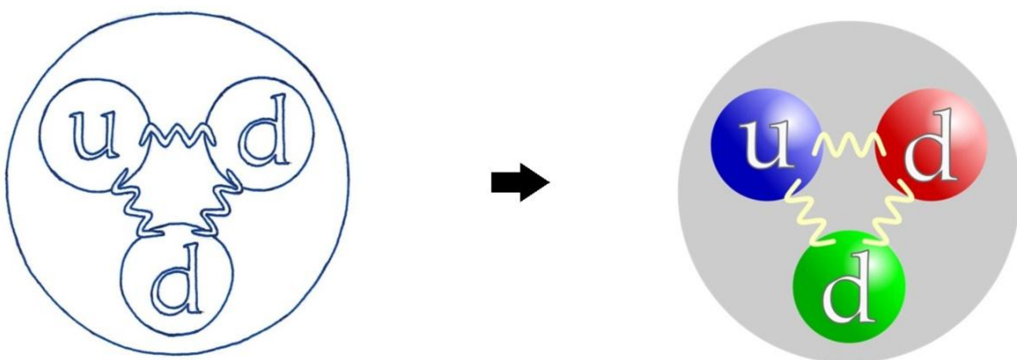
For example, if we “divide” the mass of a proton by three:

$$m_p\frac{1}{3} = \sqrt{\frac{ke^2}{c^3\pi}}\frac{1}{3}$$

then we should theoretically get the mass of one quark, since a proton is made up of three quarks. Quark composition of a proton, figure:



Quark composition of a neutron, figure:



Let's square both sides of the equation and mathematically transform as follows:

$$\frac{m_p^2}{9} = \frac{ke^2}{c^3\pi}\frac{1}{9} = \frac{ke^2}{c^3\pi}\frac{1}{\pi^2} = \frac{ke^2}{c^3\pi^3}$$

Since $\pi = 3{,}14$, then $\pi \approx 3$. From the last sequence of equations, we get:

$$\frac{c^3}{G}\frac{1}{9} = \frac{ke^2}{Gm^2}\frac{1}{\pi^3}$$

or

$$\frac{c^3}{G}\frac{1}{\pi^2} = \frac{ke^2}{Gm^2}\frac{1}{\pi^3}$$

Since the electric force between two protons is greater than the gravitational force

$$\frac{ke^2}{Gm^2} = \frac{c^3}{G}\pi = F_p\frac{\pi}{c}$$

times, then we get the ratio of the electric force and gravitation force between two electrons:

$$\frac{c^4}{G}\frac{1}{\pi^3} = F_p\frac{1}{\pi^3}$$

from which, in turn, it is possible to derive the equation for the mass of one electron, but not the equation for the mass of a quark.

The value of the mass of an electron

$$m_e = \frac{\pi k e^2}{\sqrt{c}c^3 m_p}$$

can be acquired through the mass of a proton:

$$m_p = \sqrt{\frac{ke^2}{c^3\pi}}$$

that's why we got the equation for the mass of an electron in the final form:

$$m_e = \sqrt{\frac{\pi^3 k e^2}{c^4}}$$

Exactly from the expression for the mass of an electron:

$$m_e = \frac{\pi k e^2}{\sqrt{c}c^3 m_p}$$

it is also possible to calculate the masses of proton and neutron quarks. For example, if we "replace" the elementary charge in the latter equation with the fractional electric charge of the u-quark of a proton:

$$+e \;\; \rightarrow \;\; +\frac{2}{3}e$$

then we get the following result:

$$m_e = \frac{\pi k}{\sqrt{c}c^3 m_p}e^2 = \frac{\pi k}{\sqrt{c}c^3 m_p}\frac{4}{9}e^2$$

or

$$9m_e = \frac{\pi k}{\sqrt{c}c^3 m_p}4e^2 = \frac{e^2}{\sqrt{c}c^3 m_p \varepsilon_0}$$

This would mean that the u-quark mass of a proton and a neutron would be "only" the mass of 9 electrons:

$$9m_e = \frac{e^2}{\sqrt{c}c^3 m_p \varepsilon_0}$$

Such a result is actually not very accurate. To get a more accurate result, we multiply both sides of the equation:

$$m_e = \frac{\pi k e^2}{\sqrt{c} c^3 m_p} = \frac{e^2}{\sqrt{c} c^3 m_p \varepsilon_0} \frac{1}{4}$$

or

$$4m_e = \frac{e^2}{\sqrt{c} c^3 m_p \varepsilon_0}$$

by two:

$$8m_e = \frac{2e^2}{\sqrt{c} c^3 m_p \varepsilon_0}$$

The mass of a u-quark of a proton and a neutron is therefore actually 8 electron masses, not 9 electron masses:

$$9m_e = \frac{e^2}{\sqrt{c} c^3 m_p \varepsilon_0}$$

Due to the physical analysis, we initially got an approximate value of the quark mass, but the mathematical analysis still gave us the exact value in the end. It is exactly the same when finding the value of the mass of a d-quark of a proton and a neutron. For example, the mass of an electron mass in equation:

$$m_e = \frac{\pi k e^2}{\sqrt{c} c^3 m_p}$$

let's "replace" the elementary charge with the fractional electric charge of a d-quark:

$$-e \ \rightarrow \ -\frac{1}{3} e = +\frac{2}{3} e * \left(-\frac{1}{2}\right)$$

As a result, we get:

$$m_e = \frac{\pi k}{\sqrt{c} c^3 m_p} e^2 = \frac{\pi k}{\sqrt{c} c^3 m_p} \frac{1}{9} e^2 =$$

$$= \frac{1}{\sqrt{c} c^3 m_p} \frac{1}{9} e^2 \frac{1}{4\varepsilon_0}$$

or

$$18m_e = \frac{e^2}{\sqrt{c} c^3 m_p \varepsilon_0 2}$$

Such a result is again "inaccurate" or "approximate". To get a more accurate result, we multiply both sides of the equation for the mass of a u-quark:

$$8m_e = \frac{2e^2}{\sqrt{c} c^3 m_p \varepsilon_0}$$

by two:

$$16m_e = \frac{4e^2}{\sqrt{c}c^3 m_p \varepsilon_0}$$

and subtract the mass of 1 electron from both sides of the resulting equation:

$$16m_e - 1m_e = \frac{4e^2}{\sqrt{c}c^3 m_p \varepsilon_0} - 1m_e$$

Next, we mathematically transform as follows:

$$15m_e = \frac{4e^2}{\sqrt{c}c^3 m_p \varepsilon_0} - 1m_e =$$

$$= 4\frac{e^2}{\sqrt{c}c^3 m_p \varepsilon_0} - \frac{e^2}{\sqrt{c}c^3 m_p \varepsilon_0}\frac{1}{4}$$

$$15m_e = \frac{e^2}{\sqrt{c}c^3 m_p \varepsilon_0}\left(4 - \frac{1}{4}\right)$$

Since in the latter equation we can consider an approximate value:

$$4 - \frac{1}{4} = 3{,}75 \approx 4$$

we get the equation in the following form:

$$15m_e \approx \frac{4e^2}{\sqrt{c}c^3 m_p \varepsilon_0}$$

This means that the mass of a d-quark of a proton and a neutron is equal to the masses of 15 electrons, not 16 or 18 electron masses:

$$16m_e = \frac{4e^2}{\sqrt{c}c^3 m_p \varepsilon_0}$$

$$18m_e = \frac{2e^2}{\sqrt{c}c^3 m_p \varepsilon_0}$$

The masses of quarks are many times smaller than the masses of protons and neutrons. For example, the total mass of three quarks that make up a proton is only 1% of the mass of the proton itself. It follows that the rest of the mass must exists in the energy field between the quarks, since energy and mass are equivalently related:

$$E = mc^2$$

or

$$\frac{E}{c^2} = m$$

There is a strong interaction between quarks, mediated by gluons. Virtual gluons create an energy field between quarks, just as virtual photons create an electric field in the space between electric charges. An electric field is also an energy field. Gluons and photons themselves have no inertial mass.

The course of the strong interaction potential U between quarks can be presented as:

$$U \propto \frac{1}{r} e^{-r_0 m}$$

which is actually exactly the same for the nuclear force between neutrons and protons. The nuclear force between neutrons and protons is mediated by π-mesons, or pions, which have inertial masses.

It is also worth noting here that u- and d-quarks are also different from π-mesons or pions ($\pi^+,\ \pi^-\ and\ \pi^0$), which are the mediators of nuclear forces between neutrons and protons (i.e. nucleons) in an atomic nucleus:

$$\pi^+ = u\bar{d} = +\frac{2}{3}e + \frac{1}{3}e = +e$$

$$\pi^- = d\bar{u} = -\frac{1}{3}e - \frac{2}{3}e = -e$$

$$\pi^0 = u\bar{u} = +\frac{2}{3}e - \frac{2}{3}e = 0$$

$$\pi^0 = d\bar{d} = -\frac{1}{3}e + \frac{1}{3}e = 0$$

The masses of "pions" are respectively (in electron masses):

$$\pi^0 = 264\ m_e$$

$$\pi^+ = \pi^- = 273\ m_e$$

Since pions consist of u- and d-quarks of protons and neutrons, it should also be possible to "derive" the masses of pions through them. For example, the mass of a u-quark is equal to 8 electron masses:

$$8m_e = \frac{2e^2}{\sqrt{c}c^3 m_p \varepsilon_0}$$

the mass of a d-quark, however:

$$16m_e = \frac{4e^2}{\sqrt{c}c^3 m_p \varepsilon_0}$$

Specifically, the mass of a d-quark is 15 times that of an electron:

$$15m_e \approx \frac{4e^2}{\sqrt{c}c^3 m_p \varepsilon_0}$$

According to this, the numerical value of the mass of a d-quark is equal to the sum of the masses of two u-quarks, from which in turn one electron mass is subtracted:

$$15 = 8 + 8 - 1$$

or

$$d_m = u_m + u_m - 1_m$$

If we now multiply both sides of the latter expression by the d-quark mass d:

$$dd = d^2 = ud + du - d$$

then we would see that different pairs of quarks of different pions "appear" in the resulting equation:

$$\pi^+ = u\bar{d} = +\frac{2}{3}e + \frac{1}{3}e = +e$$

$$\pi^- = d\bar{u} = -\frac{1}{3}e - \frac{2}{3}e = -e$$

$$\pi^0 = d\bar{d} = -\frac{1}{3}e + \frac{1}{3}e = 0$$

Therefore, we can write:

$$d\bar{d} = u\bar{d} + d\bar{u} - d$$

At this point, it is worth noting that positive and negative electric charge together give us a neutral electric charge:

$$\pi^+ + \pi^- = \pi^0$$

Since the mass of a d-quark was expressed with an equation:

$$d_m = u_m + u_m - 1_m$$

then the square of the d-quark mass is expressed as follows:

$$d^2 = ud + du - u - u + 1$$

In the resulting expression, we take the mass of a u-quark to the other side of the expression:

$$u + d^2 = ud + du - u + 1$$

Above we stated that the square of the d-quark mass was expressed with an “equation”:

$$d^2 = ud + du - d$$

however, it can be expressed as follows:

$$d^2 = ud + du$$

according to which the d-quark mass is only equal to the sum of the masses of two u-quarks:

$$d = u + u = 8 + 8 = 16 \neq 15$$

According to this, we obtain the expression:

$$u + d^2 = ud + du + u$$

or

$$u\bar{d} + d\bar{u} + u = d\bar{d} + u$$

which would give us the mass of a neutrally charged pion in electron masses:

$$(8 * 16) + (8 * 16) + 8 = 256 + 8 = 264$$

or

$$\pi^0 = 264\, m_e$$

A similar analysis would apply if we derived the masses of electrically charged pions. For example, in the expression for the mass of a pion with a neutral electric charge:

$$u + d^2 = ud + du - u + 1$$

let's move another mass of one u-quark to the other side of the equals sign:

$$u + u + d^2 = ud + du + 1$$

As a result, we get:

$$2u + d^2 = ud + du + 1$$

If we now take as the value of the squared mass of a d-quark:

$$d^2 = ud + du$$

and the sum of the masses of two u-quarks would be "roughly" equal to the mass of 17 electrons:

$$2u \approx 17m_e \neq 16m_e \neq 15m_e$$

then we would obtain the following expression:

$$2d\bar{u} + 2u = d\bar{d} + 2u$$

which gives us the masses of electrically charged pions in electron masses:

$$u\bar{d} + d\bar{u} + u + \bar{u} = d\bar{d} + 2u = 273m_e$$

or

$$\pi^0 + u = 264 + 8 + 1 = 256 + 17 = 273\ m_e$$

$$\pi^0 + \bar{u} = 264 + 8 + 1 = 256 + 17 = 273\ m_e$$

or

$$\pi^+ = \pi^- = 273\ m_e$$

However, the latter expressions show the "strange" d-quark mass (in electron masses):

$$2u \approx 8m_e * 2 \approx 17m_e \approx \frac{4e^2}{\sqrt{c}c^3 m_p \varepsilon_0}$$

although in reality the mass of a d-quark is 15 times that of an electron:

$$15m_e \approx \frac{4e^2}{\sqrt{c}c^3 m_p \varepsilon_0}$$

Such an “exact” mass of a d-quark was obtained when we, in equation:

$$16m_e = \frac{4e^2}{\sqrt{c}c^3 m_p \varepsilon_0}$$

subtract the mass of one electron from both sides:

$$16m_e - 1m_e = \frac{4e^2}{\sqrt{c}c^3 m_p \varepsilon_0} - 1m_e$$

Now, instead of subtracting, we add the mass of one electron:

$$16m_e + 1m_e = \frac{4e^2}{\sqrt{c}c^3 m_p \varepsilon_0} + 1m_e$$

which results in:

$$17m_e = \frac{4e^2}{\sqrt{c}c^3 m_p \varepsilon_0} + 1m_e =$$

$$= 4\frac{e^2}{\sqrt{c}c^3 m_p \varepsilon_0} + \frac{e^2}{\sqrt{c}c^3 m_p \varepsilon_0}\frac{1}{4}$$

or

$$17m_e = \frac{e^2}{\sqrt{c}c^3 m_p \varepsilon_0}\left(4 + \frac{1}{4}\right)$$

Since

$$4 + \frac{1}{4} = 4{,}25 \approx 4$$

then we can also write the approximate value of the mass of a d-quark in the following form:

$$17m_e \approx \frac{4e^2}{\sqrt{c}c^3 m_p \varepsilon_0}$$

Derivations of the masses of proton, neutron, and electron as particles purely from the "structure of spacetime" are EXTREMELY IMPORTANT for the following fundamental reasons:

1. The masses m of particles determine the wavelengths λ of these same particles, including the Compton wavelengths:

$$\lambda = m_p t_p \frac{c}{m}$$

2. The masses of proton and neutron determine the strong interaction and also the radius of action of the nuclear force. For example, the sphere of influence of the strong interaction overlaps, for example, with the size of a proton itself, which in turn is determined by the mass of a proton.

3. The masses of protons, neutrons and electrons also determine the general structure and dimensions of atoms.

4. Protons, neutrons and electrons are the main constituents of the visible matter of the entire universe, or baryonic matter. For example, the entire science of chemistry is based only on the structures of matter that consist of protons, neutrons, and electrons.

5. Through particle masses, it is possible to calculate the "binding energy", "specific binding energy" and also the "mass defect" of a nucleus. The last three concepts are mainly discussed in nuclear physics:

   The "binding energy" of a nucleus is equal to the work that must be done to move the nucleons of a nucleus to such a distance from each other that they no longer affect each other.

   The binding energy per nucleon describes the strength and relative stability of the bond between the nucleons of a nucleus. This physical quantity is called "specific binding energy".

   When a nucleus is completely fissioned, the total mass of its component particles, or nucleons, differs from the mass of the nucleus as a whole by a certain amount. This difference is called the "mass defect". The mass defect can be used to find the energy released during the formation of a nucleus $E = mc^2$, which expresses the relationship between the mass defect and the binding energy of the nucleus.

6. Through the masses of protons and neutrons, the masses of quarks inside them can also be derived. However, three valence quarks make up only 1% of the mass of a proton, for example. The rest of the proton's mass comes from interactions between quarks and gluons. Photons and gluons, however, have no mass.

7. The Coulomb barrier, or energy barrier, is a spherical energy barrier around the atomic nucleus, which is created by the positive electric charges of the protons in an atomic nucleus. It also exists for the electric charge of a single proton, such as in a hydrogen atom. The Coulomb energy barrier is a boundary beyond which there is a region in which the repulsions of other positively charged particles are manifested. However, inside there is a region where there is a nuclear force that holds nucleons, or nuclear particles, together. Due to the Coulomb energy barrier, positively charged particles, i.e. atomic nuclei, are prevented from approaching each other to such a distance that the nuclear force which binds the nucleons together would start to act. A very high energy is required to overcome the energy barrier. This kind of energy is only found in stars that undergo thermonuclear reactions. However, a single neutron can also pass through the energy barrier, because it has no electric charge.

In the points mentioned above, there is a statement that the masses of protons, neutrons and electrons also determine the general structure and dimensions of atoms. This statement needs further explanation. For example, when an electron "orbits" around a proton, i.e. around the nucleus of a hydrogen atom, there exists centripetal force F:

$$F = \frac{mv^2}{r_n} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n^2}$$

or

$$mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n}$$

It can be seen from the latter equation that the electron's centripetal force F depends on the electron's mass m, in addition to other factors. From the expression for the centripetal force F:

$$F = ma = \frac{mv^2}{r}$$

we can "derive" the speed of an electron in a hydrogen atom in a circular orbit around the nucleus:

$$v = \sqrt{\frac{Fr}{m}} = \sqrt{\frac{(8{,}2 * 10^{-8}\ N)(5{,}3 * 10^{-11}\ m)}{9{,}1 * 10^{-31}\ kg}} \approx$$

$$\approx 2{,}2 * 10^6\,\frac{m}{s}$$

In the latter, m is the mass of an electron, r is the Bohr radius, and F is the electric force between a proton and an electron. Without the mass of an electron, the spin rate in a hydrogen atom cannot be calculated. We can write the equation for the kinetic energy of a hydrogen atom as follows:

$$E_{kin} = \frac{mv^2}{2}$$

or

$$E_{kin} = \frac{1}{8\pi\varepsilon_0}\frac{e^2}{r_n}$$

The potential energy of an electron in the electric field of the nucleus is therefore:

$$E_{pot} = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n}$$

Kinetic and potential energy give us the equation for total energy of a hydrogen atom in the following form:

$$E_n = -\frac{1}{8\pi\varepsilon_0}\frac{e^2}{r_n}$$

In the Bohr theory, there is the "postulate of allowed orbits, or the quantum rule", which tells us that "the stationary states of an atom correspond to the orbiting of an electron in certain specific orbits, in which the absolute value of the momentum of an electron's momentum is a multiple of Planck's constant h":

$$mvr_n = n\frac{h}{2\pi}$$

Consequently, we get the expression for the centripetal force F of an electron in a hydrogen atom in the following form:

$$\frac{n^2h^2}{4\pi^2mr_n^2} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n} = F$$

from which, in turn

$$r_n = \frac{\varepsilon_0 h^2}{\pi m e^2}n^2$$

If n = 1, then we get the value of the radius of a hydrogen atom, or the "Bohr radius":

$$r_1 = \frac{\varepsilon_0 h^2}{\pi m e^2} \approx 5{,}29 * 10^{-11}\ m$$

through which it is also possible to present the radii of all other allowed orbits:

$$r_n = r_1 n^2$$

According to the equation for the total energy of an atom and the quantum rule, we can also find the "energy of the stationary states of an atom":

$$E_n = -\frac{me^2}{8\varepsilon_0^2 h^2}\frac{1}{n^2}$$

according to which the energy of an atom's ground state (that is, when n = 1) would be as follows:

$$E_1 = -\frac{me^2}{8\varepsilon_0^2 h^2} = -2{,}168 * 10^{-18}\, J = -13{,}5\; eV$$

Therefore, the energy of the stationary states of an atom can also be expressed only in "electron volts":

$$E_n = -\frac{13{,}5}{n^2} eV$$

The potential of the electric field is $= \frac{E_{pot}}{q}$, from which the potential energy manifests as $E_{pot} = \varphi q$. The charge of the electron is the elementary charge q = -e, and therefore the potential energy of an electron in an atom is expressed as follows: $E_{pot} = -\varphi e$. e is the elementary charge. In an atom, the electron is located in the electric field of the +e positive charge of the nucleus. Its potential at a distance r_n from the nucleus is $\varphi = k\frac{e}{r_n}$, in which

$$r_n = \frac{h^2}{kme^2}n^2 \quad \text{or} \quad r_n = n\frac{h}{mv_n}\,,$$

where the quantum number is n = 1, 2, 3 ... and

$$v_n = \frac{nh}{mr_n}\,.$$

Therefore, we get an expression for the potential energy of an electron: $E_{pot} = -k\frac{e^2}{r_n}$. The potential energy of an electron in a hydrogen atom is -4,35 * 10^{-18} J, but the field strength at the location of the electron belonging to the hydrogen atom is 5 * 10^{11} V/m.

Since the potential energy U of an electron in an atom depends only on the distance from the atomic nucleus:

$$U = U(r) = -k\frac{e^2}{r}$$

then it is also described by the basic equation of quantum mechanics, i.e. the Schrödinger equation of stationary states:

$$-k\frac{e^2}{r} = E + \frac{h^2}{2M}\Delta$$

or

$$-k\frac{e^2}{r}\varphi = E\varphi + \frac{h^2}{2M}\Delta\varphi$$

or

$$-\frac{h^2}{2M}\Delta\varphi - k\frac{e^2}{r}\varphi = E\varphi$$

In this case, the Laplace operator Δ is presented in "spherical coordinates" to show the conservation of angular momentum:

$$\Delta = \Delta_r - \frac{1}{r^2 h^2}\hat{\vec{L}}^2$$

In turn, the radial part of the Laplace operator manifests itself in it:

$$\Delta_r = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial}{\partial r}\right)$$

The potential energy U of an electron in a hydrogen atom:

$$U = -\frac{Ze^2}{r} = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$$

in which Ze is the electric charge of an atomic nucleus and r is the distance between a nucleus and an electron, can also be expressed through the form of the Schrödinger equation:

$$U\psi = \frac{Ze^2}{r}\psi = \frac{h^2}{2m_e}\left(-\Delta\psi - \frac{2m_e}{h^2}E\psi\right)$$

In this case, we replaced the energy U in the Schrödinger equation with the potential energy of the electron in a hydrogen atom:

$$\Delta\psi + \frac{2m_e}{h^2}\left(E + \frac{Ze^2}{r}\right)\psi = 0$$

Since the energy field is mostly centrosymmetric, we present the latter equation in spherical coordinates:

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial\psi}{\partial r}\right) + \frac{1}{r^2 sin\theta}\frac{\partial}{\partial\theta}\left(sin\theta\frac{\partial\psi}{\partial\theta}\right) +$$

$$+\frac{1}{r^2 sin^2\theta}\frac{\partial^2\psi}{\partial\varphi^2} + \frac{2m_e}{h^2}\left(E + \frac{Ze^2}{r}\right)\psi = 0$$

where $\Delta\psi$ is the Laplace operator. The resulting equation has univalent, finite, and continuous solutions for arbitrary positive values of energy and discrete negative values of energy, which are equal to:

$$E_n = -\frac{m_e e^4 Z^2}{2h^2 n^2}$$

in which $n = 1, 2, 3, \dots$.

On the trapped surface of spacetime, the electric force and the gravitational force are equal. We derived the formula for this equation from equation:

$$R = \frac{GM}{c^2} = \sqrt{\frac{e^2 G}{4\pi\varepsilon_0 c^4}}$$

where e is the elementary electric charge:

$$e = 1{,}602 * 10^{-19}\ C$$

and the radius R indicates the radius of the trapped surface of spherically shaped spacetime:

$$R = 1{,}3807 * 10^{-36}\ m$$

If we multiply the latter expression by 4π:

$$4\pi R = 1{,}73415 * 10^{-35}\ m$$

then the algebraic result "almost" coincides with the value of the Planck length l:

$$l_p = \sqrt{\frac{Gh}{c^3}} = 1{,}616 * 10^{-35}\ m$$

In case of 4πR we would also get the value of the mass M:

$$\frac{4\pi R}{G} c^2 = M = 2{,}3 * 10^{-8}\ kg$$

which "almost" coincides with the value of the Planck mass m:

$$m_p = \sqrt{\frac{hc}{G}} \approx 2{,}2 * 10^{-8}\ kg$$

The interrelationships between the elementary charge e, the Planck length l and the Planck mass m show that all fundamental constants of the universe are inextricably linked.

The Schwarzschild radius R indicates the size of a spherical trapped surface in, or the Schwarzschild surface, on which spacetime is curved to infinity, i.e. the physical existence of time and space has ceased:

$$R = \frac{GM}{c^2} = \sqrt{\frac{e^2 G}{4\pi\varepsilon_0 c^4}}$$

Time and space also cease to exist on the scale of the Planck length l:

$$4\pi R = 1{,}73415 * 10^{-35}\ m$$

or

$$l = \sqrt{\frac{Gh}{c^3}} = 1{,}616 * 10^{-35}\ m$$

This means that on scales smaller than the Planck length l, the universe no longer has a physical existence. In this way, the Planck length l forms the smallest possible scale of space that uniformly covers the entire three-dimensional space of the universe. We call this the "Planck surface S". This means that the smaller the spatial scale we get, the closer we get to the Planck surface S.

At this point, we have to explain how 4πR "appears" in the equation:

$$\frac{4\pi R}{G} c^2 = M$$

It's actually very simple. For example, from the mutual relation between the Schwarzschild and Nordström radii:

$$R = \frac{GM}{c^2} = \sqrt{\frac{e^2 G}{4\pi\varepsilon_0 c^4}}$$

or

$$R^2 = \frac{e^2 G}{4\pi\varepsilon_0 c^4}$$

we get 4πR right away:

$$4\pi R = \frac{e^2 G}{R\varepsilon_0 c^4} = 4\pi \frac{GM}{c^2}$$

Since there an equivalence principle applies to mass and energy:

$$E = mc^2 = \frac{mc^2}{2} = \frac{E}{2}$$

and there is also a relationship between the speed of light c and Planck's constant h:

$$\frac{1}{c^4} \approx \frac{h}{2\pi}$$

then we see that 4π is cancelled out nicely on one side of the equation:

$$4\pi R = 4\pi \frac{GM}{c^2} = 4\pi \frac{h}{2\pi} G \frac{E}{2} = hGE$$

As a result, we get the relation used above:

$$4\pi R = \frac{GM}{c^2}$$

or

$$\frac{4\pi R}{G}c^2 = M$$

in which this time: $E = mc^2$ ja $\frac{1}{c^4} \to h$.

From the latter equation for mass M, we derived the equation for the Schwarzschild radius R:

$$R = \frac{GM}{c^2}$$

Since we can express mass M purely through energy E:

$$E = mc^2 = \frac{mc^2}{2} = \frac{E}{2}$$

or

$$M = \frac{E}{c^2 2}$$

and Planck's constant h actually appears in the equation:

$$\frac{1}{c^4} \approx \frac{h}{2\pi} = h$$

then according to them we get the equation for the Schwarzschild radius R as follows:

$$R = \frac{GE}{c^4 2} = \frac{h}{2\pi}\frac{GE}{2} = \frac{hGE}{4\pi}$$

from which 4πR in turn appears:

$$4\pi R = hGE$$

However, if we now consider only such relations between energy E and Planck's constant h:

$$E = mc^2$$

and

$$\frac{1}{c^4} = h$$

we will get the equation presented above in the following form:

$$4\pi R = \frac{GE}{c^4}$$

or

$$4\pi R = \frac{GM}{c^2}$$

It is possible to convert mathematically in this way, since from the latter equation we get:

$$4\pi R = \frac{GE}{c^4}$$

or

$$4\pi R = hGE$$

according to which it is possible to use 4π expediently as follows:

$$R = \frac{hGE}{4\pi} = \frac{h}{2\pi} G \frac{E}{2} = \frac{GE}{c^4 2}$$

From the resulting equation, we see that there are "exact" relationships between energy E and Planck's constant h:

$$E = \frac{mc^2}{2} = \frac{E}{2}$$

and

$$\frac{1}{c^4} \approx \frac{h}{2\pi}$$

2.3 Fundamental constants of the universe

Science has tried to study physical phenomena even at the smallest distances in space and to find the smallest time intervals in the universe. For example, quantum electrodynamics applies at least to distances of 10^{-15} cm. The smallest experimentally confirmed time period is less than 10^{-25} seconds. It has also been speculated that finding a mini black hole with a mass of 10^{15} grams would also allow finding the smallest upper path of length, which is about 10^{-23} cm. However, studying such distances requires a stream of particles with an energy of 10^{10} gigaelectronvolts, which must be generated in laboratories. However, it is currently not possible to perform experiments with such high energy.

Some dimensional analyses show that the smallest length L should also have a corresponding density p. We can get this relationship if we consider certain constants:

$$p = \frac{h}{cL^4}$$

where h is Planck constant and c is the speed of light in vacuum. It is believed that the given density p is also the highest possible density of matter. But the density of a black hole manifests itself as follows:

$$p = \frac{c^6}{G^3 m^2}$$

where c is the speed of light in vacuum, G is the gravitational constant, and m is the mass. The latter relation shows that as the density of a black hole increases, the mass of the black hole decreases. However, if the density of the smallest possible hole is considered to be equal to the largest possible density, then the smallest possible length appears and it is 10^{-23} cm. However, this means that the smallest possible mass of a black hole is 10^{15} grams.

Numerical values of the constants that determine the strength or intensity of various interactions can be determined by nature randomly (for example, the speed of light c in vacuum, or the speed of movement of ordinary space c in relation to hyperspace), or they can actually have any value. This means that, for example, the gravitational constant G MUST appear in the equation of the gravitational force described by Newton, since the magnitude of the difference between gravitational force and electric force MUST be consistent with the rest energy E in nature:

$$E = mc^2$$

The analysis of the relationship between gravitational force and electric force suggests that it is not actually the numerical values of the constants that determine the strength or intensity of the interactions that are important, but the circumstances that determine the relationship between the different interactions. This physically means that, for example, numerical values of the gravitational constant G

$$G = \frac{c^4}{F}$$

and electric force coefficient k

$$c^2 = \frac{1}{\varepsilon_0 \mu_0} = \frac{4\pi k}{\mu_0}$$

can be determined by nature randomly, BUT the relationship between these two different interactions is determined by the expression for the rest energy E known from the theory of special relativity

$$E = mc^2$$

For example, electric force F is greater than gravitational force

$$F = \frac{c^4}{G}$$

times precisely because of the expression for the rest energy E, and this relationship remains the same (and consequently also the existence of the universe), if the numerical values of the constants should be completely different. This is the basic physical content of the "chance theory", which derives from the previous and also from the entire following mathematical analysis: the numerical values of the constants that determine the strength or intensity of various interactions can actually be determined by nature randomly (for example, the speed of light c in vacuum, or the speed of movement of ordinary space c in relation to hyperspace)

$$\sqrt[4]{GF} = c$$

or they can actually be of any value, BUT the important thing here is simply that the relationships between different interactions (for example, how many times the electric force F is greater than the gravitational force)

$$F = \frac{c^4}{G}$$

is determined by the expression for rest energy E

$$E = mc^2$$

which in turn results from the physics of time and space, or in this case from the physics theory of time travel. Time and space are the basic forms of matter and matter of the universe.

In the following, we show the interrelationships between some fundamental constants, which are in good agreement with the previously presented theory. It is enough to see and analyze a few connections to reach the conclusions that were previously presented.

For example, we can directly derive Planck length l and Planck time t from the equation for gravitational potential U:

$$U = \frac{GM}{R}$$

We express the mass M in turn from the rest energy relation:

$$M = \frac{E}{c^2}$$

and energy E in turn from the uncertainty relation between time t and energy E:

$$E = \frac{h}{2}\frac{1}{t}$$

Equation for the gravitational potential thus takes the following form:

$$U = G\frac{h}{2}\frac{1}{c^2 t}\frac{1}{R} = G\frac{h}{2}\frac{1}{l^2 c}$$

The gravitational potential is related to the Schwarzschild radius R as follows:

$$c^2 = \frac{2GM}{R} = 2U$$

which in turn gives us the greatest possible gravitational potential in the entire universe:

$$\frac{c^2}{2} = U$$

Consequently, we can write the equation U:

$$U = G\frac{h}{2}\frac{1}{l^2 c}$$

in the following form:

$$l^2 = \frac{Gh}{c^3}$$

Indeed, this is the Planck length:

$$l_p = \sqrt{\frac{Gh}{c^3}} = \sqrt{\frac{h\frac{l_p^2c^3}{h}}{c^3}} = 1{,}616\ 229(38) * 10^{-35}\ m$$

on the smaller space scales of which there is no longer any physical reality or the existence of the universe. Knowing the definition of time t from classical mechanics:

$$t = \frac{l}{v}$$

we can also derive the Planck time period:

$$t^2 = \frac{l^2}{c^2} = \frac{Gh}{c^5}$$

or

$$t_p = \sqrt{\frac{Gh}{c^5}} = 5{,}39121 * 10^{-44}\ s$$

time periods smaller than which no longer make physical sense in the universe. The quotient of the Planck length and the Planck time gives us the speed of light c, or "Planck speed v":

$$v^2 = \frac{l^2}{t^2} = \frac{Ghc^5}{c^3Gh} = c^2$$

or

$$c = \frac{l_p}{t_p} = 2{,}99792458 * 10^8\ \frac{m}{s}$$

If we consider the formula for the quantum energy E:

$$E = hf = h\frac{c}{\lambda} = h\frac{c}{r}$$

to be equal to the potential energy U of a gravitational field:

$$U = E = \frac{GMm}{r} = \frac{Gm^2}{r} = \frac{hc}{r}$$

then we immediately get the value of the Planck mass:

$$m_p = \sqrt{\frac{hc}{G}} = \sqrt{\frac{hc}{\frac{l_p^2 c^3}{h}}} = \frac{h}{l_p}\frac{1}{c} = 2{,}176435 * 10^{-8}\ kg$$

All previous analysis and reasoning were based on de Broglie's equation for wavelength λ:

$$\lambda = \frac{h}{mc} = \frac{h}{p}$$

according to which Planck's constant h is defined:

$$h = mc\lambda$$

However, if we only use Planck mass, Planck length, and Planck time, we get the definition of Planck constant h as follows:

$$\frac{h}{2\pi} = m\frac{l_p}{t_p}\lambda = \frac{m_p l_p^2}{t_p}$$

or

$$h = \frac{2\pi m_p l_p^2}{t_p} = 6{,}6260755 * 10^{-34}\ Js$$

In the equation for quantum energy:

$$E = hf$$

or

$$mc^2 = hf$$

we can also express Planck's constant h in terms of Planck mass, Planck length and Planck time as follows:

$$mc^2 = \frac{2\pi m_p l_p^2}{t_p} f$$

In the following, we assume that it is the reduced Planck constant h:

$$mc^2 = \frac{m_p l_p^2}{t_p} f$$

Let's move one term to the other side of the equation:

$$m t_p c^2 = m_p l_p^2 f$$

and transform mathematically as follows:

$$m\frac{t_p^2c^2}{l_p^2} = m\frac{c^2}{c^2} = \frac{E}{c^2} = m = m_pt_pf =$$

$$= m_pt_p\frac{1}{t} = m_pt_p\frac{c}{\lambda}$$

As a result, we can get the electron mass m:

$$m_e = m_pt_p\frac{c}{\lambda} \approx 9{,}10938 * 10^{-31}\ kg$$

if λ would be the Compton wavelength for an electron ($\lambda = 2{,}4263102367(11) * 10^{-12}\ m$). However, if we use the previously obtained expression:

$$m\frac{t_p^2c^2}{l_p^2} = m_pt_pf$$

transform mathematically in another way:

$$\frac{l_pc^2}{m_pt_pf} = \frac{l_p^3}{mt_p^2}$$

then we get the relation for the gravitational constant G as a result:

$$\frac{c^3}{m_pf} = \frac{l_p^3}{m_pt_p^2} = G = 6{,}67259 * 10^{-11}\ \frac{Nm^2}{kg^2}$$

The latter can also transform as follows:

$$\frac{ctc^2}{m_p} = \frac{l_p^3}{m_pt_p^2} = G$$

due to which the gravitational constant G manifests as follows:

$$G = \frac{l_p}{m_p}c^2 = \frac{l_p^2c^3}{h}$$

and Planck frequency f:

$$f_p = \frac{c^3}{m_pG}$$

However, from the expression for Planck mass:

$$m_p = \sqrt{\frac{hc}{G}}$$

we can, in principle, also get the value of the mass of a neutron:

$$m_n = m_p t_p \frac{c}{\lambda} \approx \sqrt{\frac{hc}{G}} \sqrt{(6\pi^2 10^{-40})} \approx$$

$$\approx \sqrt{(6\pi^2 10^{-40}) \frac{hc}{G}} \approx 1{,}674927 * 10^{-27}\ kg$$

if λ would be the Compton wavelength for a neutron ($\lambda = 2{,}1001941552 * 10^{-16}\ m$). The electron mass was expressed as a relation:

$$m_e = m_p t_p \frac{c}{\lambda}$$

but it can also be expressed as follows:

$$m_e = \frac{\alpha_e m_p l_p}{r_e}$$

Let's prove the latter as the following equation:

$$\frac{\alpha_e m_p l_p}{r_e} = m_p t_p \frac{c}{\lambda}$$

The equation is eventually cancelled out to a simple equation:

$$\frac{\alpha_e}{r_e} = \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

or

$$\alpha_e = \frac{r_e}{\lambda_e} = \frac{1}{\lambda_e} r_e = \frac{1}{\lambda_e}\left(\frac{1}{4\pi\varepsilon_0} \frac{e^2}{m_e c^2}\right) =$$

$$= \frac{1}{\lambda_e}\left(k \frac{e^2}{E_e}\right) = \frac{1}{137}$$

which can be presented in more detail as follows:

$$\frac{e^2}{4\pi\varepsilon_0 hc} \frac{1}{r_e} = \frac{1}{137} * \frac{1}{r_e} = \frac{1}{\lambda}$$

In the formula describing the series of spectral lines of a hydrogen atom, R is the Rydberg constant: $R = 1{,}0974 * 10^7 m^{-1}$ and the radius of an electron is: $r_e = 2{,}8179403227(19) * 10^{-15}\ m$. It is not difficult to see that the resulting relation describes the well-known quantum energy E:

$$\frac{e^2}{4\pi\varepsilon_0} \frac{1}{r_e} = h \frac{c}{\lambda} = hf$$

or

$$E = hf$$

We can also find the value of the mass of an electron purely from the expression for the electric field energy E of an elementary charge e ($1e = 1{,}6021892 * 10^{-19}\ C$):

$$E = mc^2 = k\frac{e_e^2}{r_e} = \frac{1}{4\pi\varepsilon_0}\frac{e_e^2}{r_e}$$

in which case we get

$$m = \frac{1}{c^2}E = \frac{1}{c^2}\frac{1}{4\pi\varepsilon_0}\frac{e_e^2}{r_e} = \varepsilon_0\mu_0\frac{1}{4\pi\varepsilon_0}\frac{e_e^2}{r_e} =$$

$$= \frac{\mu_0}{4\pi}\frac{e_e^2}{r_e} = \frac{K}{2}\frac{e_e^2}{r_e}$$

or

$$m_e = 10^{-7}\frac{e_e^2}{r_e} = 9{,}109 * 10^{-31}\ kg$$

We can also find the "electric ratio factor" k from the expression for the electric field energy E:

$$E = mc^2 = k\frac{q^2}{l}$$

according to which the equation:

$$k = \frac{mc^2 l}{q^2} = \frac{ml}{q^2}\frac{l^2}{t^2} = \frac{ml^3}{q^2t^2}$$

can be transformed using Planck mass, Planck length, Planck time and Planck’s electric charge, giving us the value of k:

$$k_e = \frac{m_p l_p^3}{q_p^2 t_p^2} = \frac{1}{4\pi\varepsilon_0} = 9 * 10^9\frac{Nm^2}{C^2}$$

The "Planck’s electric charge" also manifests itself through this:

$$q_p = \sqrt{\frac{m_p l_p^3}{k_e t_p^2}} = \sqrt{4\pi\varepsilon_0 hc} =$$

$$= \frac{e}{\sqrt{\alpha_e}} = 1{,}8755459 * 10^{-18}\ C$$

Using the definitions of Planck mass and Planck's gravitational constant, we can present Newton's equation of gravity:

$$F = G\frac{Mm}{r^2}$$

in the following form:

$$F = \frac{l_p^2 c^3}{h} \frac{\frac{h}{l_p}\frac{1}{c}\frac{h}{l_p}\frac{1}{c}}{r^2} = \frac{hc}{r^2}$$

The latter manifests through the Planck length as follows:

$$F = \frac{h}{l_p}\frac{c}{l_p}$$

At this point it should also be noted that the square of the speed of light c is related to the magnetic constant and the electric constant:

$$c^2 = \frac{1}{\varepsilon_0 \mu_0}$$

but the difference between the numerical values of the magnetic constant and the electric constant is due to the fact that the latter relationship would also be consistent with other fundamental constants of the universe. For example, from the equation for the electric field energy E:

$$mc^2 = E = k\frac{e_e^2}{r_e} = \frac{1}{4\pi\varepsilon_0}\frac{e_e^2}{r_e}$$

we can be directly "derive" the numerical value of the mass of an electron:

$$m = \frac{1}{c^2}E = \frac{1}{c^2}\frac{1}{4\pi\varepsilon_0}\frac{e_e^2}{r_e} =$$

$$= \varepsilon_0\mu_0\frac{1}{4\pi\varepsilon_0}\frac{e_e^2}{r_e} = \frac{\mu_0}{4\pi}\frac{e_e^2}{r_e} = \frac{K}{2}\frac{e_e^2}{r_e}$$

or

$$m_e = 10^{-7}\frac{e_e^2}{r_e} = 9{,}109 * 10^{-31}\ kg$$

where r_e is the Bohr radius, μ_0 is the magnetic constant and e is the elementary charge, or in this case the electric charge of an electron:

$$1e = 1{,}6021892 * 10^{-19}\ C$$

For example, this is why the numerical value of the magnetic constant must be "different" from the numerical value of the electric constant, and they should not be equal to each other. However, we can also derive the numerical value of the electric constant from the expression for the energy E of an electric field:

$$E = mc^2 = k\frac{q^2}{l}$$

if we transform it mathematically as follows:

$$k = \frac{mc^2 l}{q^2} = \frac{ml}{q^2}\frac{l^2}{t^2} = \frac{ml^3}{q^2 t^2}$$

From the obtained expression, it can clearly be seen that if we use the Planck mass, Planck length and Planck time, we get the value of the electric constant k:

$$k_e = \frac{m_p l_p^3}{q_p^2 t_p^2} = \frac{1}{4\pi\varepsilon_0} = 9 * 10^9 \frac{Nm^2}{C^2}$$

The latter equation shows Planck's electric charge, which in turn is related to the fine structure constant:

$$q_p = \sqrt{\frac{m_p l_p^3}{k_e t_p^2}} = \sqrt{4\pi\varepsilon_0 hc} =$$

$$= \frac{e}{\sqrt{\alpha_e}} = 1{,}8755459 * 10^{-18}\ C$$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Author's declaration

The author have declared him have no conflict of interest with regard to this content and ethics committee/IRB approval is not relevant to this content.

Methods

This work sets out a science of physics that would enable a person to move in real time into the past and into the future. Developing this specific science and technology will create new opportunities to explore human history and also to move in space. The overall method of study of all work is purely theoretical physics. For example, the hypothesis that is largely erected in this work is derived in theory. But at the same time, all these hypotheses are entirely in line with the generally accepted physics theories that exist.

In this work, the presented mathematical derivations and equations are not numbered. This is because there is no direct need and this work is constantly updated over time (in the form of new versions).

Data availability statement: data sharing not applicable to this content as no datasets were generated or analysed during the current study.

About the company

"*MLK Technology and Science Ltd*" is a startup company primarily engaged in scientific research on wormholes and technology development. The official data of the company can be seen on the websites:

1) https://ariregister.rik.ee/eng/company/17008425/

2) https://orcid.org/0000-0002-3223-6099

3) Company homepage: https://www.technologyandscience.eu

4) See more here: https://zenodo.org/communities/time_travel/

Area of activity: scientific research and development, research and experimental development on natural sciences and engineering, other research and experimental development on natural sciences and engineering. The company is registered in the Republic of Estonia (EE), which is a member state of the European Union (EU).

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