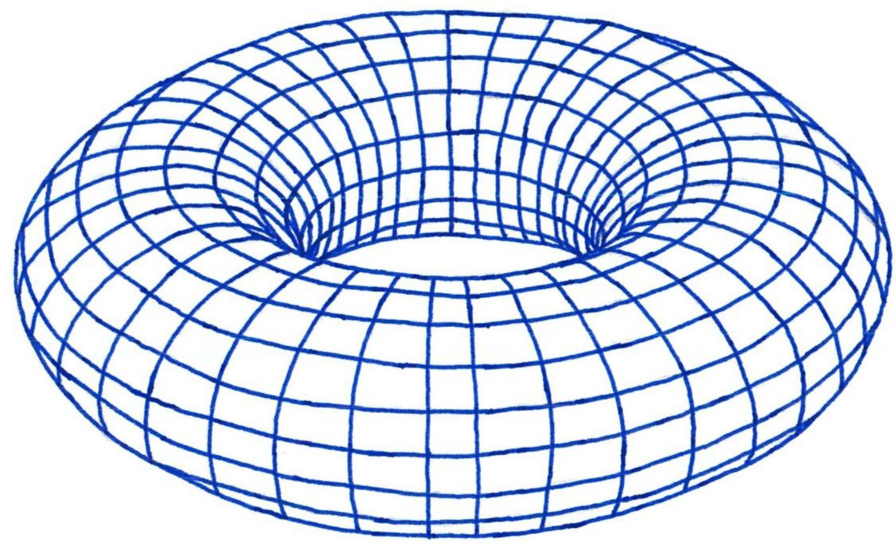
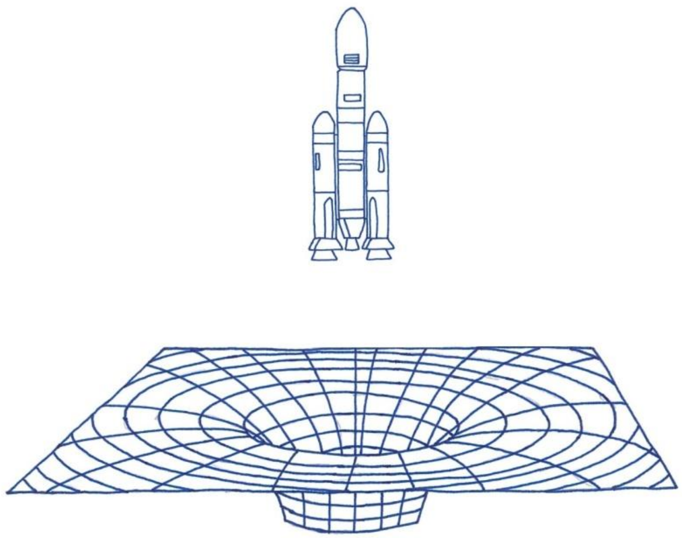


QUANTUM GRAVITY AND THE CREATION OF WORMHOLES

Marek-Lars Kruusen's

technology and science



Company: MLK Technology and Science Ltd

Date and location: June 2024, Tallinn, Estonia (EE), European Union (EU).

Author (including graphic design): Marek-Lars Kruusen

Official website: *https://www.technologyandscience.eu*

NOTE: This is the first part and the second version.

Ministry of Education and Research of Estonia: *https://www.etis.ee/CV/Marek-Lars_Kruusen/eng/*

The author can be contacted by email: *mlk@technologyandscience.eu*

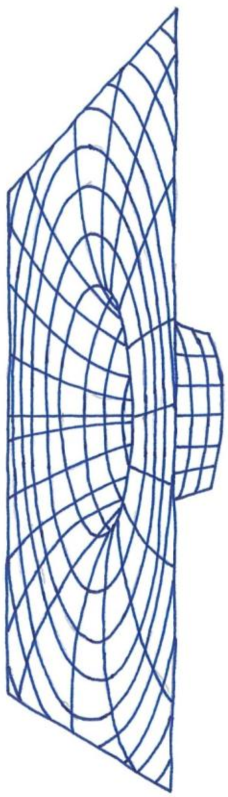
General introduction

Quantum gravity is a very important research topic in theoretical physics because it is believed to bridge quantum mechanics and Einstein's theory of general relativity. This may be true, but quantum gravity is important to basic science primarily because it would show how gravity works on an extremely small scale of spacetime, the quantum level. This work presents many new discoveries that reveal the nature of gravity at the quantum level. Albert Einstein described how gravity works on the macro- and mega-level (i.e. the level of planets and galaxies), but not on the quantum level. In order to understand gravity at the quantum level, it is first necessary to know Einstein's theory of general relativity, with which this work begins. In this paper, Albert Einstein's theory of general relativity has been presented and derived as simply as possible, which means that all irrelevant aspects of general relativity have been omitted. Modern theoretical physics tries to simplify existing theories as much as possible, eliminating all irrelevant information. General relativity can be mathematically extremely complex and a very bulky physical theory, but in this work it is presented and also derived in the most direct and simple way that has not been done anywhere and ever before. This is necessary in particular for understanding quantum gravity.

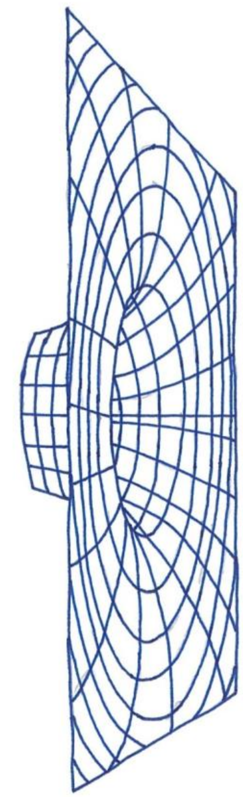
Another comprehensive topic is the physics of wormholes. The physical and mathematical interpretation of wormholes has actually been known for about a hundred years, but their technical creation has not been possible until now. However, in this work, apart from the nature of the wormhole, its technical feasibility is also shown, which has not been presented before. In particular, one specific part of the technology for creating wormholes (the outer part of the machine) is described, which is currently being processed by the United States Patent and Trademark Office (in 2023 – 2024) (1). Thus, the inventor of such technology is licensed by the USPTO. One of the biggest obstacles to the technical creation of wormholes was the production of the necessary energy, but the new discoveries presented in this work show that this is not necessary. The key to the creation of wormholes lies in the changes or creation of energy fields that occur exactly at the speed of light. Physical states that change or arise at the speed of light are also accompanied by the emergence of abstract geometric surfaces with time and space curved to infinity. The actual creation of wormholes is crucial to humanity's plans for the future. They would be practically indispensable for, for example, space travel to great distances, and wormholes would also allow people to travel in time to the past and the future. Time travel could be used in the study of human history and would be a very good tool for accurate weather forecasting, for example. For a long time, wormholes were considered the realm of science fiction and fantasy literature, and in some cases even pseudoscience. However, new discoveries concerning the possibility of their creation, which are thoroughly presented in this work, make the existence of wormholes a tangible reality.

This work is primarily aimed at an academic audience, such as students, graduate students, lecturers, researchers, but also interested parties, industrialists and even managers of technology companies and organizations. This work requires the readers to have university-level knowledge of theoretical physics and to a lesser extent of engineering. This work is a part of a larger research work, the content of which is the development of the physical theory of time travel and its technology (2). References concerning it are also presented in this work.

CONTENTS



Quantum gravity



1 Quantum gravity: introduction

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.

The fields that mediate electromagnetic, weak and strong interactions are all energy fields. Likewise, the Higgs field is also an energy field. The field has energy. However, a gravitational field is not an energy field, because the force of gravity results from the curvature of spacetime. A gravitational field does not have energy, but a body can have potential energy while in a gravitational field. Since the gravitational field is not an energy field, there cannot be such particles or "gravitons" that would mediate the gravitational interaction. Gravitational interaction is mediated only by the curvature of spacetime. Gravitons therefore cannot exist. From this follows the fact that there are only two types of fields in the universe: one type is energy fields, and the other is the kind of fields "caused" by the curvature of spacetime.

According to the laws of quantum electrodynamics, or quantum field theory, an electromagnetic field can be viewed as a collection of virtual photons or a stream of them. However, a gravitational field is a curvature of spacetime produced by a very large mass of a body. The gravitational field is not an energy field, so the gravitational interaction cannot be mediated by particles. Quantum field theory describes vacuum polarization, according to which virtual particle-antiparticle pairs are constantly formed in space, which live for a while and then annihilate. For example, in quantum field theory, a virtual electron-positron pair can exist in vacuum at most: $t = 1 * 10^{-22}\ sec$. There are similar connections here with the gravitational field, but the gravitational field does not create particles, but instead creates black holes. Black holes appear and disappear in very short periods of time, similar to pairs of particles in vacuum. If pairs of particles created in vacuum are called "virtual", then in principle black holes created in a gravitational field can also be called "virtual", since in both cases they cannot be detected experimentally.

According to the quantum gravity theory, spacetime is curved according to the Schwarzschild metric (or Einstein's gravitational field tensor equation) up to 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. This means that the distance between two points in space can only decrease up to the Planck length l, after which the distance between two points in space "instantly" becomes zero. However, at the same time, the distances between spatial points and time periods can be infinitely large.

The sudden transition to the infinite curvature of spacetime on an extremely small scale of spacetime (i.e. the Planck length l) is the main content of this quantum gravity theory. The Planck length l constitutes 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.

1.1 Inert and heavy mass

1.1.1 Introduction

Albert Einstein created the general theory of relativity almost ten years after the creation of the special theory of relativity. He generalized it to any background systems, because only inertial background systems were considered in the special theory of relativity. However, non-inertial background systems are also taken into account in general relativity. These are systems moving with acceleration. Therefore, the theory is more general. Under the influence of gravitational force, free bodies move with acceleration in gravitational field. General relativity is therefore a relativistic gravitational field theory.

There is no difference between the force of gravity and the force of inertia. The entire theory of general relativity is built on such an equivalence principle. Such a principle is proved by all experimental experiments that show the uniformity or equality of heavy and inert mass, but only up to a certain limit:

$$\left|\frac{m_g - m}{m_g}\right| \leq 10^{-12}$$

where $m_g = m$. Precise dimensions have not yet been easily obtained. This clearly shows that it is possible to replace the gravitational field with a field of inertial forces. For example, the centrifugal force of a spinning spacecraft pushes bodies toward the outer walls of the spacecraft. The wall becomes a floor on which a person can walk in a spinning spaceship. Such emerging centrifugal force (or inertial force) is similar to gravitational force. In this way, the existence of gravity in a spaceship is simulated.

The equality of heavy and inert mass is called the weak equivalence principle, but the bending of a light beam by gravity follows from the strong equivalence principle.

The mathematical description of rapidly moving systems leads to the concept of non-homogeneous space. Space becomes curved around massive bodies. There, free bodies begin to move with acceleration. This is how gravity is explained. Accelerated movement of a free body in curved space is as self-evident as uniform linear movement in "straight" or Euclidean space.

Gravity is the curvature of spacetime, that is, it is described by the geometry of spacetime. A gravitational field is not an energy field because it contains no energy, although a body has potential energy in a gravitational field. And so we can talk about gravity as a spacetime field (that is, a time and space field). There are two types of matter fields in the universe: energy fields and spacetime fields.

1.1.2 Inert and heavy mass

Only inertial background systems are considered in special relativity. In an inertial background system, the law of inertia applies. The law of inertia is that a body moves uniformly and in a straight line as long as nothing changes that state. The question arises that if time and space transformations (i.e. time dilation and body length contraction) occur in inertial background systems, can they also occur in non-inertial background systems. In inertial background systems, time and space transformations appear as the speed of motion increases, but non-inertial background systems are gravitational fields. Gravitational force, and with it the force field, is related to the mass of a body. Inertial background systems deal primarily with inertial mass. According to Newton's second law (F = ma or a = F/m), the inertia of a body with an inert mass is characterized by its resistance to change in its state of motion. For example, the more mass a body has, the more force must be applied to make the body move or stay still. But in non-inertial background systems (such as gravitational fields) the concept of heavy mass is used. The greater the mass of a body, the greater the gravitational force it produces.

Both Newton's second law and Newton's law of gravity comprise mass. Mass is a measure of the inertia of a body - this is in Newton's second law, but mass also has the property of attraction - this is in Newton's law of gravity. However, are heavy mass and inert mass the same?

Newton's law of gravity is known to be as follows (in case of Earth's gravity):

$$F = G\frac{m_g M_M}{{R_M}^2}$$

where the heavy mass of a body is m_g, the heavy mass of the Earth is M_M, and the radius of the Earth is R_M. Under the influence of gravitational force, a body gets an acceleration a, but not gravitational acceleration (or g). Such acceleration of the body must be proportional to the ratio of the inertial mass of the body and the gravitational force:

$$a = \frac{f}{m_{in}} = G\frac{M_M m_g}{{R_M}^2 m_{in}}$$

However, all experimental tests show that the acceleration a is the same for all bodies. Therefore, if the gravitational acceleration is the same, then the acceleration must be the same. The factor

$$G\frac{M_M}{{R_M}^2}$$

is the same for all bodies. Therefore, for all bodies, the m_g/m_{in} ratio is also the same. And thus only one conclusion can be drawn - namely, inert mass and heavy mass are one and the same for all bodies. They are equal - then:

$$a = \frac{f}{m_{in}} = G\frac{M_M m_g}{{R_M}^2 m_{in}}$$

or

$$a = G\frac{M_M}{{R_M}^2}$$

The Earth's mass M_M can be obtained from the latter relation. If we know the radius of the Earth's orbit R_{or} and the period of the Earth's rotation T, then the mass of the Sun M_p can also be determined. The gravitational force that exists between the Earth and the Sun causes acceleration of the Earth $\omega^2 R_{or}$ ($\omega = 2\pi/T$). Consequently:

$$M_M \omega^2 R_{or} = G\frac{M_M M_p}{{R_{or}}^2}$$

From this, it is possible to calculate the mass of the Sun. Analogously, the masses of other celestial bodies can also be calculated in this way.

Inert and heavy mass are equivalent. This means that it is not possible to determine whether the observed body is located in a gravitational field or in a background system moving with acceleration. For example, in a weightless state in a falling elevator or in a spaceship orbiting the Earth, it is not possible to determine the presence of acceleration or a gravitational field. Mathematically, this is expressed in curved space. For example, the orbit of a spacecraft in flat or Euclidean space is equivalent to a straight line in curved space. A straight line in curved space is called a geodesic line. A trajectory with sufficient curvature can be straight in curved space. A straight line is the shortest path between two points in space. With a negative curvature, the so-called geometry of hyperbolic spaces was developed in 1826 by N. Lobachevsky, and the geometry of spaces with arbitrary curvature was created in 1854 by B. Riemann. Albert Einstein linked the curvature of space to quantities that describe mass and motion. When solving Einstein's equation, a world line of the observed body is obtained in curved space, which is determined by the masses of other bodies. The world line is the movement path of the body in four spaces. In case of a four-dimensional coordinate system (or curved spacetime), three spatial axes and one time axis are used. The moment of time is multiplied by the speed of light to make it the fourth dimension of space. This results in four coordinates: x, y, z and ct.

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:

$$U(R) = \int_{\infty}^{R} -Fds\,, \qquad s = R$$

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:

$$t^{\prime} = \frac{t}{y}$$

Therefore, the journey duration is shortened for the travelers:

$$l^{\prime} = t^{\prime} v = \frac{t}{y} v = \frac{l}{y} = l\sqrt{1 - \frac{v^2}{c^2}}$$

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

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

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 Planck time and Planck length

We can directly derive the Planck length l and Planck time t from the equation for the gravitational potential U:

$$U = \frac{GM}{R}$$

if we express mass M from the relation for rest energy:

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

and energy E in turn from the uncertainty relation between time t and energy E:

$$E = \frac{h}{2}\frac{1}{t}$$

The 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 for U:

$$U = G\frac{h}{2}\frac{1}{l^2 c}$$

in the following form:

$$l^2 = \frac{Gh}{c^3}$$

This is already the Planck length:

$$l = \sqrt{\frac{Gh}{c^3}} = 1{,}616\ 229(38) * 10^{-35}\ m$$

on smaller spatial scales of which there is no longer a perceptible physical reality, or the existence of the universe. Knowing the definition of time t from classical mechanics:

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

we can derive the Planch time:

$$t^2 = \frac{l^2}{c^2} = \frac{Gh}{c^5}$$

or

$$t = \sqrt{\frac{Gh}{c^5}} = 5{,}39121 * 10^{-44}\ s$$

time periods smaller than which no longer have a perceptible physical meaning in the universe. In the mathematical derivation of the Planck time and the Planck length, we used the relation between the rest energy E:

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

and the uncertainty relation between quantum energy E and time t:

$$E = \frac{h}{2}\frac{1}{t}$$

> It is worth mentioning here that the Planck time t and the Planck length l are the basis for all other quantities that start with the name "Planck" (for example, Planck energy, Planck temperature, Planck density, Planck mass, etc.).

Time and space cease to exist at the scale of the Planck length l:

$$l = \sqrt{\frac{Gh}{c^3}} = 1{,}616 * 10^{-35}\ m$$

This means that on scales smaller than the Planck length l, the universe no longer has 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.

The quotient of the Planck length l and the Planck time t gives us the speed of light c, or the “Planck speed v”:

$$v^2 = \frac{l^2}{t^2} = \frac{Ghc^5}{c^3Gh} = c^2$$

or

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

1.4 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:

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

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

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

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:

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

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

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

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 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):

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

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

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

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

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

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

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

However, taking the square of the latter expression

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

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

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

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

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

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.

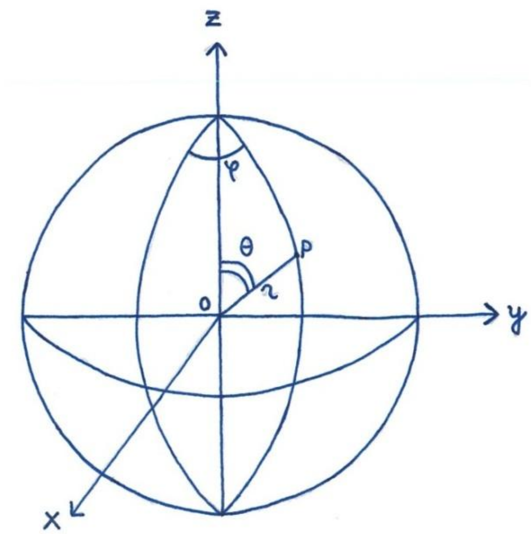


Figure: Spherical coordinates.

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.

1.5 Differential equation of the gravitational field

Before analyzing the relationship between the theory of relativity and quantum mechanics in depth, we derive the basic equations of Einstein's gravitational field, the correct derivation of which was presented by David Hilbert in 1915. This derivation starts from the Einstein-Hilbert influence functional equation:

$$S = \int \sqrt{-g} d^4 x \left[\frac{1}{2k^2}(R - 2\Lambda) + \mathcal{L}_M\right]$$

in which the determinant of the metric tensor manifests itself

$$g \equiv \det(g_{\mu\nu})$$

R is the Ricci scalar, $\mathcal{L}_M$ is the term containing matter fields, and Λ is the so-called cosmological constant. G is Newton's gravitational constant in relation

$$k^2 \equiv 8\pi G$$

and the region of integration is taken over the entire spacetime. Since the principle of least effect ($\delta S = 0$) applies in fundamental physics and following the contravariant components $g^{\mu\nu}$ of the inverse metric, we can present the Einstein-Hilbert effect functional equation in the following form:

$$0 = \delta S = \int \frac{\delta\sqrt{-g}}{\delta g^{\mu\nu}} \left[\frac{1}{2k^2}(R - 2\Lambda) + \mathcal{L}_M\right] \delta g^{\mu\nu} d^4 x =$$

$$= \int \left[\frac{1}{2k^2}\left(R \frac{\delta\sqrt{-g}}{\delta g^{\mu\nu}} + \sqrt{-g} \frac{\delta R}{\delta g^{\mu\nu}} - 2\Lambda \frac{\delta\sqrt{-g}}{\delta g^{\mu\nu}} - 2\sqrt{-g} \frac{\delta\Lambda}{\delta g^{\mu\nu}}\right) + \frac{\delta\sqrt{-g}\mathcal{L}_M}{\delta g^{\mu\nu}}\right] \delta g^{\mu\nu} d^4 x$$

The part in square brackets is equal to zero, since the latter equation must hold for any variation of $\delta g^{\mu\nu}$. Next, we divide the term in brackets by$\sqrt{-g}$, resulting in:

$$\frac{R}{\sqrt{-g}} \frac{\delta\sqrt{-g}}{\delta g^{\mu\nu}} + \frac{\delta R}{\delta g^{\mu\nu}} - \frac{2\Lambda}{\sqrt{-g}} \frac{\delta\sqrt{-g}}{\delta g^{\mu\nu}} - 2 \frac{\delta\Lambda}{\delta g^{\mu\nu}} = \frac{-2k^2}{\sqrt{-g}} \frac{\delta\sqrt{-g}\mathcal{L}_M}{\delta g^{\mu\nu}}$$

The resulting equation is essentially the basic equation of Einstein's gravitational field. For example, in the first and third member of the latter equation, the "metric definition variation" is expressed as:

$$\delta\sqrt{-g} = -\frac{1}{2\sqrt{-g}}\delta g = -\frac{1}{2}\sqrt{-g}(g_{\mu v}\delta g^{\mu v})$$

due to which we obtain the first member of Einstein's equation in the following form

$$\frac{R}{\sqrt{-g}}\frac{\delta\sqrt{-g}}{\delta g^{\mu v}} = \frac{1}{2}Rg^{\mu v}$$

and the third member in the following form

$$\frac{2\Lambda}{\sqrt{-g}}\frac{\delta\sqrt{-g}}{\delta g^{\mu v}} = \Lambda g^{\mu v}$$

Since the definition of a Ricci scalar manifests itself as a relation:

$$R = g^{\mu v}R_{\mu v}$$

then thus we can express the second member of the Einstein's equation as:

$$\frac{\delta R}{\delta g^{\mu v}} = \frac{\delta(g^{\mu v}R_{\mu v})}{\delta g^{\mu v}} = R_{\mu v}\frac{\delta g^{\mu v}}{\delta g^{\mu v}} + g^{\mu v}\frac{\delta R_{\mu v}}{\delta g^{\mu v}} = R_{\mu v}\frac{\delta g^{\mu v}}{\delta g^{\mu v}} + 0 = R_{\mu v}$$

The cosmological constant is independent of contravariant components, and the fifth member in the Einstein's equation is proportional to the energy-momentum tensor:

$$-\frac{2}{\sqrt{-g}}\frac{\delta\left(\sqrt{-g}\mathcal{L}_M\right)}{\delta g^{\mu v}} = T_{\mu v}$$

The basic equation of Einstein's gravitational field thus becomes:

$$R_{\mu v} - \frac{1}{2}g_{\mu v}R + \Lambda g_{\mu v} = k^2 T_{\mu v}$$

The latter equation can also be represented through the Einstein tensor $G_{\mu v}$:

$$G_{\mu v} + \Lambda g_{\mu v} = 8\pi G T_{\mu v}$$

in which the Einstein tensor describes the geometry of spacetime. The latter equation actually contains 16 equations, therefore 10 independent equations remain due to tensor symmetries. However, four more connections are added by Bianci's identity:

$$\nabla^{\mu}G_{\mu v} = 0$$

The six equations that remain are not linear, and therefore the superposition principle cannot be applied to the solutions of these equations.

The basic equation of Einstein's gravitational field is also directly derived from the equation for the Schwarzschild radius R, through which it is related to quantum mechanics. The equation for the

Schwarzschild radius R is derived from the equation for the law of conservation of mechanical energy in physics, in which the kinetic energy and the potential energy U are equal to each other:

$$\frac{mv^2}{2} = U = -\frac{GMm}{R}$$

Gravitational potential U is mostly negative in physics. In the latter equation, the masses m cancels out nicely:

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

and with some simple mathematical transformations we get the equation for the Schwarzschild radius R:

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

in which case we leave the minus sign in the equation. According to the mathematical definition of rest energy E:

$$E = mc^2$$

we can also express mass M purely through energy E:

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

which gives us the equation for radius R in the following form:

$$R = -\frac{2G}{c^4}E$$

Above we proved the relation between the "reduced" Planck's constant h used in quantum mechanics and the speed of light c:

$$\frac{1}{c^4} \approx \frac{h}{2\pi} = \bar{h}$$

and this would give us the equation in the following form:

$$R = -2GE\frac{1}{c^4} = -2GE\bar{h}$$

Let us multiply both sides of the resulting equation

$$R = -\frac{2G}{c^4}E$$

by -4π:

$$-4\pi R = \frac{8\pi G}{c^4}E$$

From now on, it is very important for us that the following relation holds in this equation:

$$-4\pi R = -R$$

where

$$4\pi = 2(2\pi) = 1$$

This is important because we need to finally derive the differential equation for Einstein's gravitational field. In principle, it is also possible to prove the validity of the latter equations. For example, in the equation derived above:

$$R = -2GE\frac{1}{c^4} = -2GE\bar{h}$$

instead, we consider that Planck's constant h is not actually "reduced":

$$\frac{2\pi}{c^4} \approx 2\pi\bar{h} = h$$

This gives us the equation in the following form:

$$R = -2GEh = -2GE\frac{2\pi}{c^4} = -\frac{4\pi G}{c^4}E$$

or

$$R = -\frac{4\pi G}{c^4}E$$

Let’s multiply both sides of the resulting equation by two:

$$2R = -\frac{8\pi G}{c^4}E$$

and take the number two to the other side of the equals sign of the equation:

$$R = -\frac{8\pi G}{c^4}\frac{E}{2}$$

Regarding the cosmology of the universe, we derived and through it also proved the validity of the following equation:

$$\frac{E}{2} = \frac{mc^2}{2} = mc^2 = E$$

which again gives us the initial form:

$$R = -\frac{8\pi G}{c^4}E$$

or

$$-R = \frac{8\pi G}{c^4}E$$

If we assume that the resulting equation is a Ricci scalar R, which in turn is related to the Einstein tensor G_{ik} and the Ricci tensor R_{ik}:

$$g^{ik}G_{ik} = G = g^{ik}\left(R_{ik} - \frac{1}{2}g_{ik}R\right) = R - 2R = -R$$

or

$$G = -R$$

then we obtain the equation in the following form:

$$G = \frac{8\pi G}{c^4} E$$

or

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

In the latter equation, only G and E are variables. The energy E is in the theory general relativity described by the "energy-momentum tensor" T^{ik}:

$$T^{ik} = \frac{1}{2} M_i c^2 = \frac{E}{2}$$

or

$$T^{ik} = M_i c^2 = E$$

and the form of the G tensor of the variable is as follows:

$$G_{ik} = R_{ik} - \frac{1}{2} g_{ik} R$$

Consequently, the variables G and E can be described by the corresponding tensors, due to which we get the equation in the final form:

$$G_{ik} = \frac{8\pi G}{c^4} T^{ik}$$

or

$$G^{ik} = \frac{8\pi G}{c^4} T^{ik}$$

which is actually the differential equation for Einstein's gravitational field.

The validity of the approximate value of Planck's constant h can be demonstrated through the Schwarzschild radius R formula:

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

For instance, expressing mass m through energy $E = mc^2$, we obtain the equation in the form of

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

Through a mathematical transformation of this expression

$$\frac{1}{2GE} R = \frac{1}{c^4}$$

we can derive the quantum mechanical equation $px = h$, where the following equalities must hold:

$$\frac{1}{2GE} = p = mc$$

$$R = x$$

$$\frac{1}{c^4} \approx h$$

The validity of the momentum p expression

$$\frac{1}{2GE} = p = mc$$

can be further proven as follows: for instance, by performing the following mathematical transformation

$$\frac{1}{2Gm} = Ec$$

and multiplying both sides of the equation by c^2:

$$\frac{c^2}{2Gm} = \frac{1}{R} = Ec^3$$

From the resulting equation, we obtain

$$\frac{1}{c^3} = ER$$

and if we divide both sides of this equation by the speed of light c

$$\frac{1}{c^4} = E\frac{R}{c} = Et$$

taking into account the definition of velocity v from classical mechanics

$$v = c = \frac{s}{t}$$

we arrive at the uncertainty relation between energy E and time t:

$$h = Et$$

which aligns with the dimension of Planck's constant h: "energy times time".

It is also possible to obtain the differential equation for Einstein's gravitational field through the mass m of the equation for radius R obtained above:

$$R = -\frac{8\pi G}{c^2}m$$

or

$$-R = \frac{8\pi G}{c^2}m$$

In this case, we see that the only variables are the radius –R and the mass m, and the remaining members of the equation form a constant:

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

In the following, we express the variables –R and m as “tensors” arising from the theory of general relativity. For example, in Albert Einstein's theory of general relativity, the basic equation for the gravitational field is defined by the Einstein tensor G as follows:

$$G_{ik} = R_{ik} - \frac{1}{2} g_{ik} R$$

and if we multiply both sides of this equation by the "metric tensor" g

$$g_{ik} = g^{ik}$$

we obtain, as a result, a negative radius –R:

$$g^{ik} G_{ik} = g^{ik} \left(R_{ik} - \frac{1}{2} g_{ik} R \right) = R - 2R = -R$$

Hence, we can write:

$$g^{ik} G_{ik} = \frac{8\pi G}{c^2} m$$

In quantum field theory, the "energy-momentum tensor" is defined through Lagrangian mathematics:

$$T_{\mu v} = L\delta_{\mu v} - \sum_A \frac{\partial L}{\partial u_{A,v}} u_{A,\mu}$$

where

$$u_{A,\mu} = \frac{\partial u_A}{\partial x_\mu}$$

Through the energy-momentum tensor, the "energy-momentum vector" is also defined in Lagrangian mathematics:

$$P_\mu = -i \int T_{\mu 4} d^3 x$$

the fourth component of which defines the energy E:

$$E = \int H\, d^3 x = -\int T_{44} d^3 x$$

in which the Hamiltonian density manifests itself as:

$$H(x) = \sum_A \frac{\partial L(x)}{\partial \dot{u}_A(x)} \dot{u}_A(x) - L(x)$$

In the tensor mathematics of Albert Einstein's theory of general relativity, the energy tensor can be expressed as follows:

$$T^{\alpha y} = \frac{1}{2} M_i c^2 = \frac{E}{2}$$

In this we see the expression for rest energy:

$$E = mc^2$$

which is divided by two:

$$\frac{mc^2}{2} = \frac{E}{2}$$

However, in the theory of general relativity, as well as in tensor mathematics, the "energy-momentum tensor" is defined by a differential equation:

$$T^{ik} = m_0 \frac{dx^i}{ds}\frac{dx^k}{ds} + F^{ik}$$

multiplying both sides of which by the metric tensor g results in a positive mass m:

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

or

$$g_{ik}T^{ik} = m$$

Consequently, we can, in the equation derived above

$$g^{ik}G_{ik} = \frac{8\pi G}{c^2} m$$

Replace the mass m as follows:

$$g^{ik}G_{ik} = \frac{8\pi G}{c^2} g_{ik}T^{ik}$$

where the metric tensor g is symmetric:

$$g^{ik} = g_{ik}$$

Thus, the metric tensor is cancelled out nicely from the equation, as a result of which we obtain the basic equation for a gravitational field:

$$G_{ik} = \frac{8\pi G}{c^2} T^{ik}$$

or

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

However, here some corrections must be taken into account. For example, if the equation previously held:

$$g^{ik}G_{ik} = -R$$

then the Einstein tensor G itself equals as follows:

$$G_{ik} = R_{ik} - \frac{1}{2} g_{ik}R$$

or, therefore

$$G_{ik} \neq -R$$

This, however, gives the basic equation for the gravitational field in the following form:

$$R_{ik} - \frac{1}{2} g_{ik}R = \frac{8\pi G}{c^2} T^{ik}$$

or

$$R_{ik} - \frac{1}{2} g_{ik}R = \frac{8\pi G}{c^2} T_{ik}$$

Exactly the same analysis applies to the equation:

$$g_{ik}T^{ik} = m$$

For example, if the metric tensor g "cancels out" in this equation, the equation no longer holds:

$$T^{ik} \neq m$$

The equation holds only in case:

$$T^{ik} = mc^2 = E$$

and this gives us the differential equation for the gravitational field in the following form:

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

The latter equation is expressed in terms of energy E.

However, in the following, we will analyze the form of the basic equation for the gravitational field, which was just obtained first:

$$G^{ik} = \frac{8\pi G}{c^4}T^{ik}$$

or

$$G^{ik} = R^{ik} - \frac{1}{2}g^{ik}R = \frac{8\pi G}{c^4}T^{ik}$$

Such a differential equation for the gravitational field is expressed in terms of mass m. In these equations, the term $+\Lambda g_{\mu\nu}$, which is supposed to describe the dark energy of the universe, is missing. In the latter equation, the metric tensor g can also be expressed as a determinant:

$$g_{\mu\nu} = \begin{bmatrix} \left(1 - \frac{2GM}{rc^2}\right) & 0 & 0 & 0 \\ 0 & -\left(1 - \frac{2GM}{rc^2}\right)^{-1} & 0 & 0 \\ 0 & 0 & -r^2 & 0 \\ 0 & 0 & 0 & -r^2 sin^2\theta \end{bmatrix}$$

The mass of a body curves the surrounding spacetime, and the curvature of spacetime in turn affects the movements of bodies in it. This means that the existence of matter and energy affect the geometry or metric of spacetime, as well as the movement of that matter or energy in spacetime. This is what A. Einstein's tensor equation describes mathematically:

$$G_{ik}\big(g(x)\big) = -\frac{8\pi G}{c^4}T_{ik}$$

or

$$G_{\mu\nu} = R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu}$$

where G is the Einstein tensor consisting of a combination of the Ricci tensor R and the metric tensor g. The motion of matter in the gravitational field is described by the tensor T. The indices μ and ν are different components of the tensors. Einstein's tensor G shows how physical bodies bend the geometry of the surrounding spacetime and how the curvature of the same spacetime causes bodies to move.

If we use the definition of the Planck force:

$$F_p = \frac{c^4}{G} = \frac{hc}{l_p^2}$$

then we would obtain the Einstein's tensor in the following form:

$$G_{ik} = \frac{8\pi l_p^2}{hc} T_{ik}$$

in which Planck's constant h, Planck's length l_p, Planck's time t_p and Planck's area S_p would manifest:

$$\frac{h}{2} = \frac{S_p}{c}\frac{T_{ik}}{G_{ik}} = 4\pi l_p t_p \frac{T_{ik}}{G_{ik}}$$

Using Planck's gravitational constant, we could transform the tensor equation for Einstein's gravitational field:

$$R_{\mu\upsilon} - \frac{1}{2} g_{\mu\upsilon} R = \frac{8\pi G}{c^4} T_{\mu\upsilon}$$

to the following form:

$$R_{\mu\upsilon} - \frac{1}{2} g_{\mu\upsilon} R = \frac{8\pi \frac{l_p^2 c^3}{h}}{c^4} T_{\mu\upsilon}$$

or

$$R_{\mu\upsilon} - \frac{1}{2} g_{\mu\upsilon} R = \frac{8\pi l_p^2}{hc} T_{\mu\upsilon}$$

Since Planck's constant h is mostly reduced:

$$h = \frac{h}{2\pi}$$

then this would give us the final form of the equation:

$$R_{\mu\upsilon} - \frac{1}{2} g_{\mu\upsilon} R = \frac{16\pi^2 l_p^2}{hc} T_{\mu\upsilon}$$

Since above we got the definition for Planck's constant h used in quantum mechanics:

$$\frac{1}{c^4} \approx \frac{h}{2\pi} = \bar{h}$$

then we can write the Einstein's equations as follows:

$$G_{ik}\big(g(x)\big) = -8\pi G\bar{h} T_{ik} = -4GhT_{ik}$$

and

$$G_{\mu\nu} = R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = 8\pi G\bar{h} T_{\mu\nu} = 4GhT_{\mu\nu}$$

The latter equations show very clearly that Einstein's equations, i.e. the gravitational field, are somehow related to quantum mechanics. For a deeper understanding of the relationship between the theory relativity and quantum mechanics, let's move from the tensor formalism to the classical metric formalism of the theory of general relativity. To do this, we transform the differential equation of the gravitational field derived above:

$$G^{ik} = R^{ik} - \frac{1}{2} g^{ik} R = \frac{8\pi G}{c^4} T^{ik}$$

or

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

We multiply both sides of the equation by the metric tensor g as follows:

$$g^{ik} G_{ik} = g^{ik} \left(R_{ik} - \frac{1}{2} g_{ik} R \right) = R - 2R = -R$$

As a result, we obtain the equation:

$$g^{ik} G_{ik} = -R$$

where R is the known Schwarzschild radius. The metric tensor g is symmetric:

$$g^{ik} = g_{ik}$$

and the Einstein tensor G is also symmetric:

$$G^{ik} = G_{ik}$$

The metric tensor g also manifests itself as a four-line determinant in the theory of general relativity:

$$g_{ik} = \begin{bmatrix} \left(1 - \frac{2GM}{rc^2}\right) & 0 & 0 & 0 \\ 0 & -\left(1 - \frac{2GM}{rc^2}\right)^{-1} & 0 & 0 \\ 0 & 0 & -r^2 & 0 \\ 0 & 0 & 0 & -r^2 sin^2\theta \end{bmatrix}$$

according to which we can write the equation:

$$g^{ik} G_{ik} = -R$$

in the following form:

$$\begin{bmatrix} \left(1 - \frac{2GM}{rc^2}\right) & 0 & 0 & 0 \\ 0 & -\left(1 - \frac{2GM}{rc^2}\right)^{-1} & 0 & 0 \\ 0 & 0 & -r^2 & 0 \\ 0 & 0 & 0 & -r^2 sin^2\theta \end{bmatrix} G_{ik} = -R$$

For further analysis, we take the four-line determinant to the other side of the equals sign:

$$G_{ik} = -R \begin{bmatrix} \left(1-\frac{R}{r}\right) & 0 & 0 & 0 \\ 0 & -\left(1-\frac{R}{r}\right)^{-1} & 0 & 0 \\ 0 & 0 & -r^2 & 0 \\ 0 & 0 & 0 & -r^2 sin^2\theta \end{bmatrix}^{-1}$$

where

$$R = \frac{h}{p}$$

The resulting mathematical definition of Einstein's tensor G is significantly simpler than the tensor-mathematical formalism presented by Albert Einstein:

$$G_{ik} = R_{ik} - \frac{1}{2} g_{ik} R = G_{\mu\nu} = \left[\partial_\eta(\Gamma^\eta_{\mu\nu}) - \partial_\nu(\Gamma^\eta_{\eta\mu}) + \Gamma^\eta_{\eta\lambda}\Gamma^\lambda_{\mu\nu} - \Gamma^\lambda_{\mu\eta}\Gamma^\eta_{\nu\lambda}\right] -$$

$$-\frac{1}{2} g^{\alpha\beta} \left[\partial_\eta(\Gamma^\eta_{\alpha\beta}) - \partial_\beta(\Gamma^\eta_{\eta\alpha}) + \Gamma^\eta_{\eta\lambda}\Gamma^\lambda_{\alpha\beta} - \Gamma^\lambda_{\alpha\eta}\Gamma^\eta_{\beta\lambda}\right] g_{\mu\nu}$$

in which Christoffel symbols appear. We won't go into that kind of super complicated math here, but instead use much simpler relationships. For example, Einstein's tensor G was equal to:

$$G_{ik} = \frac{8\pi G}{c^4} T_{ik}$$

However, in case of the manifestation of the energy-momentum tensor T:

$$T_{ik} = E = mc^2 = Mc^2$$

we can write the Einstein tensor G in the following form:

$$G_{ik} = \frac{8\pi G}{c^2} M$$

or

$$G_{ik} = \frac{8\pi}{c^2} GM$$

Consequently, we can express the equation containing the four-line determinant as follows:

$$\frac{8\pi}{c^2} GM = -R \begin{bmatrix} \left(1-\frac{R}{r}\right) & 0 & 0 & 0 \\ 0 & -\left(1-\frac{R}{r}\right)^{-1} & 0 & 0 \\ 0 & 0 & -r^2 & 0 \\ 0 & 0 & 0 & -r^2 sin^2\theta \end{bmatrix}^{-1}$$

Let's take the Schwarzschild radius R to the other side of the equals sign and multiply both sides of the equation by -1 and mass m:

$$-\frac{8\pi}{c^2}\frac{GMm}{R} = m\begin{bmatrix} \left(1-\frac{R}{r}\right) & 0 & 0 & 0 \\ 0 & -\left(1-\frac{R}{r}\right)^{-1} & 0 & 0 \\ 0 & 0 & -r^2 & 0 \\ 0 & 0 & 0 & -r^2 sin^2\theta \end{bmatrix}^{-1}$$

Let’s take the square of the speed of light c to the other side of the equals sign and divide both sides of the equation by two:

$$-4\pi\frac{GMm}{R} = \frac{mc^2}{2}\begin{bmatrix} \left(1-\frac{R}{r}\right) & 0 & 0 & 0 \\ 0 & -\left(1-\frac{R}{r}\right)^{-1} & 0 & 0 \\ 0 & 0 & -r^2 & 0 \\ 0 & 0 & 0 & -r^2 sin^2\theta \end{bmatrix}^{-1}$$

In the resulting equation, we see the expression for the law of conservation of mechanical energy:

$$-\frac{GMm}{R} = U = \frac{mc^2}{2}$$

Such a form manifests itself only if

$$4\pi = 2(2\pi) = 1$$

(which was actually already "proved" above) and if the four-line determinant were equal to -1:

$$\begin{bmatrix} \left(1-\frac{R}{r}\right) & 0 & 0 & 0 \\ 0 & -\left(1-\frac{R}{r}\right)^{-1} & 0 & 0 \\ 0 & 0 & -r^2 & 0 \\ 0 & 0 & 0 & -r^2 sin^2\theta \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}$$

(in which case the Schwarzschild radius is zero, i.e. $R = 0$). Such a determinant is very easy to calculate mathematically:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix} = 1(-1)(-1)(-1) = -1$$

which gives us the following equation:

$$\begin{bmatrix} \left(1-\frac{R}{r}\right) & 0 & 0 & 0 \\ 0 & -\left(1-\frac{R}{r}\right)^{-1} & 0 & 0 \\ 0 & 0 & -r^2 & 0 \\ 0 & 0 & 0 & -r^2 sin^2\theta \end{bmatrix}^{-1} = \frac{1}{-1} = -1$$

As a result, we initially get negative kinetic energy:

$$-\frac{GMm}{R} = -\frac{mc^2}{2}$$

but that negativity actually cancels out nicely in the equation:

$$\frac{GMm}{R} = \frac{mc^2}{2}$$

Only the gravitational potential U is usually presented as negative:

$$-\frac{GMm}{R} = \frac{mc^2}{2}$$

The equation for the law of conservation of mechanical energy is derived from Newtonian mechanics, in which spacetime is flat. However, in fact our spacetime is curved, the flatness of which simply manifests itself on a very small spatial scale compared to the scale of curved spacetime. This means that flat spacetime is a special case of curved spacetime in the same way that Newtonian mechanics is a special case of general relativistic mechanics. This is what the entire previous mathematical and physical analysis proves.

The equation containing the law of conservation of mechanical energy derived above:

$$-4\pi\frac{GMm}{R} = \frac{mc^2}{2}\begin{bmatrix} \left(1-\frac{R}{r}\right) & 0 & 0 & 0 \\ 0 & -\left(1-\frac{R}{r}\right)^{-1} & 0 & 0 \\ 0 & 0 & -r^2 & 0 \\ 0 & 0 & 0 & -r^2 sin^2\theta \end{bmatrix}^{-1}$$

is presented in case of curved spacetime. However, in case of flat spacetime, the form of this equation is:

$$-\frac{GMm}{R} = \frac{mc^2}{2}\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}^{-1}$$

In the latter equation, we see that everything eventually cancels to -1:

$$-\frac{2GM}{Rc^2} = -\frac{R}{R} = -1 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}^{-1} = -1$$

If we move the determinant to the other side of the equals sign, we obtain as a result:

$$(-1)\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix} = (-1)(-1) = 1$$

In principle, the latter can also be solved in this way:

$$(-1)\begin{bmatrix}1 & 0 & 0 & 0\\0 & -1 & 0 & 0\\0 & 0 & -1 & 0\\0 & 0 & 0 & -1\end{bmatrix}=\begin{bmatrix}-1 & 0 & 0 & 0\\0 & 1 & 0 & 0\\0 & 0 & 1 & 0\\0 & 0 & 0 & 1\end{bmatrix}=-1$$

The metric tensor g is expressed as a determinant, which in this case describes a flat spacetime:

$$g_{\mu\nu}=\begin{bmatrix}1 & 0 & 0 & 0\\0 & -1 & 0 & 0\\0 & 0 & -1 & 0\\0 & 0 & 0 & -1\end{bmatrix}$$

In some cases it is also written in the following form:

$$g_{\mu\nu}=\begin{bmatrix}c^2 & 0 & 0 & 0\\0 & -1 & 0 & 0\\0 & 0 & -1 & 0\\0 & 0 & 0 & -1\end{bmatrix}$$

The metric tensor g is directly related to the metric equation of the spacetime interval. We show this by introducing the Einstein gravitational field derived above into the differential equation

$$G^{\mu\nu}=\frac{8\pi G}{c^2}T^{\mu\nu}$$

or in this case

$$g_{\mu\nu}G^{\mu\nu}=-R$$

Let's take tensor G to the other side of the equals sign:

$$g_{\mu\nu}=-\frac{R}{G^{\mu\nu}}$$

If we now multiply both sides of the equation by the tensor $dr^{\mu}dr^{\nu}$

$$g_{\mu\nu}dr^{\mu}dr^{\nu}=-\frac{R}{G^{\mu\nu}}dr^{\mu}dr^{\nu}$$

then it is equal to the metric equation of the spacetime interval:

$$g_{\mu\nu}dr^{\mu}dr^{\nu}=ds^2$$

which, when written out at length, looks like this:

$$g_{\mu\nu}dr^{\mu}dr^{\nu}=dr^{\mu}dr_{\mu}=ds^2=c^2dt^2-dx^2-dy^2-dz^2$$

However, if the coordinates of the spacetime interval equation have "an opposite sign":

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

then it can, for example, be described by the matrix:

$$g_{\mu\nu} = \begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

or

$$g_{\mu\nu} = \begin{pmatrix} -c^2 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} = \eta_{\mu\nu}$$

which also occurs in the metric equation describing flat spacetime:

$$ds^2 = \eta_{\mu\nu} dx^\mu dx^\nu$$

However, if instead of Cartesian cross coordinates:

$$(x^0, x^1, x^2, x^3) = (ct, x, y, z)$$

spherical coordinates were used:

$$(x^0, x^1, x^2, x^3) = (ct, r, \theta, \varphi)$$

and instead of a flat spacetime, we would be dealing with a curved spacetime, then it is already described by the metric tensor g presented above:

$$g_{\mu\nu} = \begin{bmatrix} \left(1 - \frac{2GM}{rc^2}\right) & 0 & 0 & 0 \\ 0 & -\left(1 - \frac{2GM}{rc^2}\right)^{-1} & 0 & 0 \\ 0 & 0 & -r^2 & 0 \\ 0 & 0 & 0 & -r^2 sin^2\theta \end{bmatrix}$$

In case of such a determinant, the form of the metric equation of the spacetime interval is as follows:

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

It is worth noting here that all tensors previously used derive from Riemannian geometrical mathematics, which studies Riemannian spaces. Riemannian spaces are “subspaces of true Euclidean space”. In Riemannian geometry, Riemannian spaces are described by the metric derived above:

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu$$

Such a metric equation can also be derived directly from the equation for rest energy:

$$E = mc^2$$

since the square of the velocity v^2 corresponds to the tensor equation in Riemannian geometry:

$$\frac{E}{m} = c^2 = v^2 = \left(\frac{ds}{d\tau}\right)^2 = g_{\mu\nu}\frac{dx^\mu}{d\tau}\frac{dx^\nu}{d\tau}$$

or

$$\frac{E}{m} = g_{\mu\nu}\frac{dx^\mu}{d\tau}\frac{dx^\nu}{d\tau}$$

If we divide both sides of the latter equation by the square of the speed c:

$$\frac{E}{mc^2} = \frac{E}{E} = 1 = g_{\mu\nu}\frac{dx^\mu}{d\tau}\frac{dx^\nu}{d\tau}\frac{1}{c^2}$$

then we get the metric equation of the spacetime interval:

$$c^2 d\tau^2 = g_{\mu\nu}dx^\mu dx^\nu$$

or

$$ds^2 = g_{\mu\nu}dx^\mu dx^\nu$$

from which

$$\frac{ds^2}{g_{\mu\nu}} = dx^\mu dx^\nu$$

Such a metric equation of the spacetime interval can also be derived from the equation for rest energy:

$$E = mc^2$$

via the corresponding equation for energy-momentum tensor T:

$$T^{\mu\nu} = m_0\frac{dx^\mu}{ds}\frac{dx^\nu}{ds} + F^{\mu\nu}$$

where $F^{\mu\nu} = 0$ and the square of speed c is expressed as:

$$c^2 = \frac{dx^\mu}{ds}\frac{dx^\nu}{ds}$$

The equation for energy-momentum tensor T

$$T^{\mu\nu} = m_0\frac{dx^\mu}{ds}\frac{dx^\nu}{ds}$$

can be mathematically transformed as follows:

$$dsds = \frac{m_0}{T^{\mu\nu}}dx^\mu dx^\nu$$

Since the mass m can also be defined only through tensors:

$$g_{\mu\nu}T^{\mu\nu} = g_{\mu\nu}\left(m_0\frac{dx^\mu}{ds}\frac{dx^\nu}{ds} + F^{\mu\nu}\right) = m_0 + g_{\mu\nu}F^{\mu\nu} = m$$

which in turn gives us the definition for the metric tensor g:

$$g_{\mu\nu} = \frac{m}{T^{\mu\nu}}$$

or

$$g_{\mu\nu} = \frac{m}{T^{\mu\nu}} = \frac{m}{E} = \frac{m}{mc^2} = \frac{1}{c^2}$$

so we get the metric equation for the spacetime interval:

$$dsds = \frac{m_0}{T^{\mu\nu}} dx^\mu dx^\nu = g_{\mu\nu} dx^\mu dx^\nu = ds^2$$

or

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu$$

In Riemannian geometry, this equation is also written like this:

$$ds^2 = drdr = u_\mu u_\nu dx^\mu dx^\nu$$

which describes the square of a line element in subspace. An elementary place vector manifests in this subspace:

$$ds = dr = u_\mu dx^\mu$$

or

$$dr = dx^\mu u_\mu$$

The member u appearing in it denotes the basis vectors of the subspace:

$$\frac{dr}{dx^\mu} = u_\mu$$

and in Riemannian geometry it equals to:

$$\frac{dr}{dx^\mu} = \frac{\partial r}{\partial x^\mu}$$

From the latter, in turn, we get:

$$dr = \frac{\partial r}{\partial x^\mu} dx^\mu$$

The position vector r is replaced by the following differential in Riemannian geometry:

$$dr = dy^\alpha e_\alpha = \frac{\partial y^\alpha}{\partial x^\mu} dx^\mu e_\alpha$$

as a result of which we get:

$$dy^\alpha = \frac{\partial y^\alpha}{\partial x^\mu} dx^\mu$$

or

$$\frac{dy^\alpha}{dx^\mu} = \frac{\partial y^\alpha}{\partial x^\mu}$$

The latter equation is obtained in Riemannian geometry by differentiating an equation equal to:

$$y^\alpha = y^\alpha(x^1, x^2, \dots, x^n)$$

It is a parametric equation of an n-dimensional subspace in Riemannian geometry, in which the parameters are the coordinates of the n-dimensional subspace, and in which

$$\alpha = 1, 2, \dots, \nu$$

In all these equations, y represents rectangular Cartesian coordinates, α is the Greek letter index, v is the number of dimensions of the space, e is the “ort”, n is the number of dimensions of the subspace, x represents the parameters or coordinates, and u is the basis vectors.

The time-invariant centrally symmetric gravitational field, i.e. the curvature of spacetime, is described by the metric equation:

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

In 1916, a scientist named Schwarzschild found such a solution, and that is why it is also called the Schwarzschild metric. In such a metric equation, gravitational time dilation was expressed as an equation:

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

or

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

and gravitational length contraction:

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

or

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

or

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

on which the metric of spacetime warped by the masses depended on.

A remarkable fact about these equations is that, for example, from the gravitational time dilation equation alone

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

the "upper limit" of the gravitational potential U follows very clearly:

$$U = \frac{c^2}{2} = const$$

and consequently also the "maximum possibility" of the gravitational force F in the universe. This means that, for example, on the Schwarzschild surface at the center of a black hole, the gravitational force F does not actually reach infinity, even though spacetime itself is curved to infinity. However, the gravitational force F and consequently the gravitational potential U can be indefinitely small.

1.6 An analysis of quantum gravity

The title of this chapter, "Analysis of Quantum Gravity," may initially refer to such a presentation that analyzes the nature of quantum gravity. However, in fact, this chapter presents and analyzes the relationship of Planck's constant h and the quantum energy equation E = hf to the equations used in general relativity. In the following, we will show the "primary relations" between general relativity and quantum mechanics, which are no longer very important today, but this part still played an important role in the historical development of quantum gravity theory.

For further analysis, we transform, for example, the time dilation equation as follows:

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

and square both sides of the equation:

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

Let’s transform again:

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

In the latter equation, the Schwarzschild radius R is expressed as equation:

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

Knowing the definition of the equation of static energy: $E=mc^2$, from which we in turn get the mathematical definition of mass M through energy E:

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

we get the equation for Schwarzschild radius R in the following form:

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

Above we proved an approximate relation for Planck's constant h used in quantum mechanics:

$$\frac{1}{c^4}\approx\frac{h}{2\pi}=h$$

and the validity of the impulse p:

$$\frac{1}{2GE}=p$$

It should be noted here that in deriving the differential equation of Einstein's gravitational field

$$G^{\mu\nu} = \frac{8\pi G}{c^4} T^{\mu\nu}$$

we considered the uncancelled Planck constant h:

$$\frac{2\pi}{c^4} \approx h \neq \overline{h}$$

In principle, we can do the same trick here, but for the sake of simplicity, we only consider the reduced Planck constant in the following:

$$\frac{1}{c^4} \approx \frac{h}{2\pi} = h$$

Consequently, we get the equation for the Schwarzschild radius R in the following form:

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

which in turn gives the equation for the gravitational time dilation in the following form:

$$1 - \left(\frac{t}{t`}\right)^2 = \frac{R}{r} = \frac{h}{xp}$$

or

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

The equation for the Schwarzschild radius R is also expressed through the gravitational potential U:

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

which gives us the following chain of connections:

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

For further analysis, we consider only two equations, which we present below as a system of equations:

$$\begin{cases} xp\left[1 - \left(\frac{t}{t`}\right)^2\right] = h \\ \dfrac{h}{xp} = \dfrac{2U}{c^2} \end{cases}$$

The equation in this system of equations:

$$\frac{h}{xp} = \frac{2U}{c^2}$$

we transform mathematically as follows:

$$pxU = \frac{hc^2}{2}$$

What we know for sure from quantum mechanics is that two different indeterminacy relations are equal:

$$px = Et$$

and this gives us the equation in the following form:

$$EtU = \frac{hc^2}{2}$$

We move the time period t to the other side of the equals sign of the equation, whereby we get the following result:

$$EU = \frac{hc^2}{2}\frac{1}{t} = hf\frac{c^2}{2}$$

In the resulting equation, the energies E mathematically cancel out nicely:

$$EU = hf\frac{c^2}{2} = E\frac{c^2}{2}$$

as a result of which we get the well-known equation of the law of conservation of mechanical energy:

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

or

$$\frac{GMm}{R} = \frac{mc^2}{2}$$

This shows the correctness of the entire previous analysis, since absolutely all laws of nature must be in accordance with the law of conservation of energy (that is, they must eventually reduce to it). However, for further analysis, we transform the equation obtained above

$$EU = hf\frac{c^2}{2}$$

Instead so that we multiply both sides of the equation by mass m:

$$EUm = hf\frac{mc^2}{2} = hf\frac{E}{2}$$

We can see that the energies E nicely cancel out mathematically again:

$$Um = \frac{hf}{2}$$

Since the gravitational potential U also manifests itself as:

$$Um = \frac{GMm}{R} = U$$

which in turn shows "dimension"

$$m = \frac{U}{U} = 1$$

then we get the equation in the following form as well:

$$U = \frac{hf}{2}$$

In the following, we recall the relation obtained above:

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

in which the gravitational potential U is manifested:

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

However, if we now consider the recently derived definition of gravitational potential U:

$$U = \frac{hf}{2}$$

then we get the following equation:

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

The latter is equal to M. Planck's equation for quantum energy E:

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

from which it can be seen that the gravitational time dilation part of the equation is equal to the mass m:

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

since in quantum mechanics the following relation holds:

$$E = mc^2 = hf$$

The remarkable fact is that the obtained strange equation for mass

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

is actually a mathematical transformation of such a time dilation equation:

$$t` = \frac{t}{\sqrt{1-m}}$$

which has no physical meaning. The mass m is not the mass of an intermediate particle in the gravitational field. However, if the tensor equation of the gravitational field derived above is taken into account in the latter equation:

$$g_{\mu\nu}G^{\mu\nu} = -R$$

then we get the equation for gravitational time dilation in the following form:

$$t` = \frac{t}{\sqrt{1-\frac{R}{r}}} = \frac{t}{\sqrt{1+(-R)\frac{1}{r}}} = \frac{t}{\sqrt{1+g_{\mu\nu}G^{\mu\nu}\frac{1}{r}}}$$

or

$$t` = \frac{t}{\sqrt{1+\frac{g_{\mu\nu}G^{\mu\nu}}{r}}}$$

which already has physical content and meaning. However, in case of the equation for mass m

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

the physical meaning and "necessity" become apparent only when the proof of the derivation of this same equation is analysed more thoroughly. It is very easy to show. For example, based on the previous analysis, we get the following relationship:

$$m = \frac{2U}{c^2} = \frac{2GMm}{c^2 r}$$

from which it can be seen that the mass m is actually with "dimension" one:

$$1 = \frac{2GM}{c^2 r}$$

From the latter, in turn, we obtain the law of conservation of mechanical energy:

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

In the expression for kinetic energy, $c^2 = v^2$ represents the escape velocity of a planet. It is interesting to note that from the equation derived above:

$$\frac{h}{xp} = \frac{2U}{c^2} = m$$

we can also define the de Broglie wavelength λ as the product of the coordinate x and the mass m:

$$\frac{h}{p} = xm = \lambda$$

according to which the mass m must also be of "dimension" one:

$$m = 1$$

This is very easy to prove. For example, we multiply both sides of the equation:

$$\frac{h}{xp} = m$$

by the square of the speed of light:

$$c^2 \frac{h}{xp} = mc^2 = E$$

As a result, we get the equation for energy E:

$$c \frac{h}{xm} = E$$

or

$$h \frac{c}{xm} = E$$

which coincides with Max Planck's equation for quantum energy E:

$$hf = E$$

According to this, the quantum frequency f must be equal to:

$$\frac{c}{xm} = \frac{v}{xm} = f$$

from which the definition of the wavelength λ can be seen:

$$xm = \lambda$$

since in mechanics the frequency f is equal to the quotient of velocity v and wavelength λ:

$$\frac{v}{\lambda} = f$$

Previously, we were able to derive the equation for mass m:

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

which gives us the equation $xm = \lambda$ in the following form:

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

If we make the following mathematical transformations specific to the theory of relativity in the latter:

$$\frac{t}{t`} = \frac{ct}{ct`} = \frac{l}{l`} = \frac{l}{l_0}$$

and

$$\frac{\lambda}{x} = \frac{R}{r}$$

then we can derive the gravitational length contraction equation known in general relativity:

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

or

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

which also describes the curvature of spacetime.

According to the theory of general relativity, the gravitational field is the curvature of spacetime. The curvature of spacetime is shown, for example, by gravitational time dilation, the validity of which has also been experimentally proven. According to the above analysis, we get this equation in the following form:

$$t` = \frac{t}{\sqrt{1 - \frac{h}{xp}}}$$

Since the product of xp can only be equal to Planck's constant h:

$$xp = h$$

we get the following result:

$$t` = \frac{t}{\sqrt{1 - \frac{h}{h}}} = \frac{t}{\sqrt{1 - 1}} = \frac{t}{0} = \infty$$

It follows from this that when time and space are curved or transformed to infinity (i.e. when the existence of time and space ceases to exist), then the laws of quantum mechanics begin to manifest. Time and space are curved, for example, on the Schwarzschild surface at the centre of a black hole, or the trapped surface of spacetime. Consequently, quantum gravity manifests ONLY on the Schwarzschild surface at the centre of the gravitational field, i.e. the trapped surface of spacetime.

However, if we transform the equation

$$t` = \frac{t}{\sqrt{1 - \frac{h}{xp}}}$$

as follows:

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

then this in turn gives us the next very important equation:

$$xp - xp\left(\frac{t}{t`}\right)^2 = h$$

It can be clearly seen from the latter equation that if the curvature of spacetime did not exist, i.e. spacetime would be completely flat:

$$t` = \frac{t}{\sqrt{1-\frac{h}{xp}}} = \frac{t}{\sqrt{1-\frac{R}{r}}} = \frac{t}{\sqrt{1-\frac{R}{\infty}}} = t$$

then we get the following result:

$$xp - xp = 0 = h$$

However, the obtained result contradicts the rules of quantum mechanics:

$$0 \neq h$$

since the product of xp cannot be less than the value of Planck's constant h and therefore cannot be equal to zero. It follows that the gravitational field, or the curvature of spacetime, cannot actually be quantized. Quantum gravity therefore does not exist. However, if the curvature of spacetime is infinite:

$$t` = \frac{t}{\sqrt{1-\frac{h}{xp}}} = \frac{t}{\sqrt{1-\frac{R}{r}}} = \frac{t}{\sqrt{1-\frac{R}{R}}} = \infty$$

we will get the following result:

$$xp - xp\left(\frac{t}{t`}\right)^2 = xp - xp\left(\frac{t}{\infty}\right)^2 = xp - 0 = xp = h$$

Such a result is already consistent with the indeterminacy relation between the coordinate x and the momentum p known from quantum mechanics:

$$xp = h$$

since the product of xp can be equal to Planck's constant h. It follows from this that when time and space are curved or transformed to infinity (i.e. when the existence of time and space ceases to exist), then the laws of quantum mechanics begin to manifest. Time and space are curved, for example, on the Schwarzschild surface at the centre of a black hole, or the trapped surface of spacetime.

A gravitational field is a curvature of spacetime caused by very large masses. This curvature of spacetime manifests itself in the fact that the more you go towards the centre of a gravitational field, the more time slows down and the distance between two points in space decreases relative to an external observer. This transformation of time and space continues up to a certain distance from the centre of the gravitational field. In physics, this distance is described by the Schwarzschild radius R. This radius indicates the distance from the centre of the gravitational field, from where spacetime has transformed to infinity, i.e. from where the infinite curvature of spacetime manifests, i.e. the absolute cessation of spacetime existence. Therefore, nothing can exist in the "region" inside the Schwarzschild radius R of the black hole, sometimes called the Schwarzschild "surface" of a hole in spacetime. This also means that there cannot be any spacetime singularity at the centre of a black hole. A singularity is simply a point from which the Schwarzschild radius R is measured, which determines the "size" of a black hole, or a hole in spacetime, or the size of an imaginary sphere in space, from which the infinite curvature of spacetime becomes progressively flatter as it moves away from the centre. Therefore, the mass of a black hole cannot exist inside the Schwarzschild surface, but is outside of it, as in case of stars and planets. The Schwarzschild surface of a black hole is perfectly spherical and does not rotate. It can only orbit another celestial body.

In the analysis presented above, we saw that when in case of the derived equation

$$xp - xp\left(\frac{t}{t`}\right)^2 = h$$

the equation $t` = \infty$ holds or time (and space together with it as well) has transformed to infinity:

$$xp - xp\left(\frac{t}{\infty}\right)^2 = h$$

then we obtained a relation of indeterminacy valid in reality:

$$xp = h$$

However, if it were Euclidean (i.e. non-curved) spacetime, i.e. $t` = t$, then such equations as

$$xp - xp\left(\frac{t}{t`}\right)^2 = h$$

and

$$xp\left(\frac{t}{t`}\right)^2 - xp = h$$

there is no longer any substantive difference as both give the equation:

$$xp - xp = h$$

which results in a relationship that is not valid in reality:

$$0 = h = const$$

Planck's constant h cannot be equal zero. However, if in the equation derived above

$$xp - xp\left(\frac{t}{t`}\right)^2 = h$$

xp is made equal to zero, then we get the equation

$$-xp\left(\frac{t}{t`}\right)^2 = h$$

which also results in a relationship that is not valid in reality:

$$-xp = h$$

since the indeterminacy relation cannot be negative. However, if in the equation

$$xp\left(\frac{t}{t`}\right)^2 - xp = h$$

xp is equal to zero, we will get the following equation

$$xp\left(\frac{t}{t`}\right)^2 = h$$

from which follows the relation of indeterminacy valid in reality:

$$xp = h$$

since in this case it is positive. For further analysis, we consider the last used connection:

$$xp\left(\frac{t}{t`}\right)^2 = h$$

in which t` = t. Let's transform the latter equation mathematically as follows:

$$x\left(\frac{t}{t`}\right)^2 = x\frac{t}{t`}\frac{t}{t`} = \frac{h}{p} = \lambda$$

from which, in turn, we get:

$$x\frac{t}{t`}\frac{t}{t`} = \lambda$$

The definition of the wavelength λ follows from the latter:

$$x\frac{t}{t`}\frac{t}{t`} = vt\frac{t}{t`} = x\frac{t}{t`} = vt = \lambda$$

or

$$vt = \lambda$$

Suppose that the speed v is equal to the speed of light c:

$$ct = \lambda$$

The resulting relation is remarkable, because it completely coincides with the equation for wavelength λ derived in the quantum mechanics section above:

$$\frac{ct}{\sqrt{1-\frac{v^2}{c^2}}} = \lambda$$

or

$$ct = \lambda\sqrt{1-\frac{v^2}{c^2}}$$

In the latter equation, the velocity v must be equal zero, which gives us exactly the same relationship:

$$ct = \lambda$$

A remarkable fact about the previous analysis is that if in our derived equation

$$xp - xp\left(\frac{t}{t`}\right)^2 = h$$

(space)time has transformed to infinity, or t` = ∞:

$$xp - xp\left(\frac{t}{\infty}\right)^2 = h$$

then we get the indeterminacy relation valid in reality:

$$xp = h$$

However, if in the equation:

$$xp\left(\frac{t}{t`}\right)^2 - xp = h$$

(space)time has not transformed, or t` = t, and xp is equal to zero:

$$xp\left(\frac{t}{t`}\right)^2 = h$$

then, as a result, we get the relation of indeterminacy also valid in reality:

$$xp = h$$

It follows very clearly from such an analysis that the fundamental indeterminacy relation of quantum mechanics arises from the infinite transformation of spacetime, i.e. the cessation of time and space:

$$t` = \infty$$

but the relation of indeterminacy also manifests itself in our ordinary Euclidean, or non-transformed spacetime:

$$t` = t$$

This means in terms of physical sciences that the wavy nature of a particle existing in our ordinary Euclidean spacetime results directly from the cessation of spacetime's existence, i.e. its infinite transformation, which would exist to us as "a non-perceptible parallel spacetime next to the whole of our perceptible Euclidean spacetime". For example, changes in "parallel spacetime" also result in changes in our ordinary Euclidean spacetime, and vice versa. This "parallel spacetime" is called "hyperspace" in the theory of time travel, and our usual perceived Euclidean spacetime is called "ordinary space". In this case, the quantum particle exists in both hyperspace and ordinary space at the same time.

1.7 Einstein's equation in cosmology

Albert Einstein's theory of general relativity is the only physics theory that describes curved spacetimes, and thus Einstein's theory of general relativity is also the basis for the entire teaching of modern cosmology, since in traditional cosmology a curved spacetime, especially curved space, is taken as the model of the expansion of the universe. The metric formalism is the most common mathematical form to describe the curvature of spacetime:

$$ds^2 = dx_0{}^2 - dx_1{}^2 - dx_2{}^2 - dx_3{}^2 = c^2dt^2 - dx^2 - dy^2 - dz^2 = c^2dt^2 - dl^2$$

from which it is possible to mathematically derive the well-known Robertson-Walker metric, which mathematically describes the expansion of spacetime of the universe. For this purpose, we present, instead of the Cartesian cross coordinate system

$$dl^2 = dx^2 + dy^2 + dz^2$$

spherical coordinates

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

since the model of expansion of the universe in cosmology is mostly the expansion of a sphere in space. As a result, we get the following equation:

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

Since the sphere is expanding, in this latter equation the quantity r is the radial coordinate moving with the coordinate system:

$$R = r = a(t)\chi$$

The radial distance R = r = a(t)χ can also be the distance between two galaxies in the universe. Consequently, we can write the spherical coordinates as follows:

$$(dl)^2 = a^2(t)\{(d\chi)^2 + K[(d\theta)^2 + sin^2\theta(d\varphi)^2]\}$$

and the Robertson-Walker metric takes the form:

$$ds^2 = c^2dt^2 - a^2(t)\{(d\chi)^2 + K[(d\theta)^2 + sin^2\theta(d\varphi)^2]\}$$

in which the values of K can be:

$$K = \begin{cases} sin^2\chi \\ \chi^2 \\ sh^2\chi \end{cases}$$

The Robertson-Walker metric form is also sometimes presented as follows:

$$ds^2 = -dt^2 + a(t)^2 \left\{ \frac{dr^2}{1-kr^2} + r^2[(d\theta)^2 + sin^2\theta(d\varphi)^2] \right\}$$

in which the values of k can be:

$$k = \begin{cases} 1 \\ 0 \\ -1 \end{cases}$$

In the Robertson-Walker metrics

$$(ds)^2 = c^2dt^2 - (dl)^2$$

in which

$$(dl)^2 = a^2(t)\{(d\chi)^2 + K[(d\theta)^2 + sin^2\theta(d\varphi)^2]\}$$

multiplier K has three different possibilities. This is because the space of the universe can be positive, negative or flat. For positive space, the value of K is:

$$K = sin^2\chi$$

and therefore k = +1. However, its ranges of variation are as follows: $\chi \in (0, \pi)$, $\theta \in (0, \pi)$, $\varphi \in (0, 2\pi)$. In case of negative space, the value of K is:

$$K = (sh\chi)^2$$

and therefore k = -1. Its ranges of variation are as follows: $\chi \in (0, \infty)$, $\theta \in (0, \pi)$, $\varphi \in (0, 2\pi)$. In case of flat space, the value of K is:

$$K = \chi^2$$

and therefore k = 0. Its ranges of variation are: $\chi \in (0, \infty)$, $\theta \in (0, \pi)$, $\varphi \in (0, 2\pi)$.

The quantity r is the radial coordinate moving with the coordinate system:

$$R = r = a(t)\chi$$

The radial distance $R = r = a(t)\chi$ can also be the distance between two galaxies in the universe. Since this distance increases with time due to the metric expansion of the universe, we can take the time derivative of it as follows:

$$v = \frac{dR}{dt} = \frac{d}{dt}(a(t)\chi) = \chi\frac{da(t)}{dt} = \chi\dot{a}$$

in which the derivative with respect to time is represented by a dot on a:

$$\dot{a} = \frac{da(t)}{dt}$$

From the radial distance $R = r = a(t)\chi$ we get the following relation:

$$\chi = \frac{R}{a}$$

and as a result, we get Hubble's law, which is widely known in cosmology:

$$v = \frac{R}{a}\dot{a} = \frac{\dot{a}}{a}R = HR$$

where the Hubble constant H is

$$H = \frac{\dot{a}}{a}$$

or

$$\dot{a} = Ha$$

The Hubble constant H depends on time:

$$H \sim \frac{1}{t}$$

The previous analysis can be understood in a simplified way so that, considering the radial coordinate R in Hubble's law $v = HR$:

$$R = a(t)\chi$$

the time derivative is the velocity $v = \dot{a}\chi$ and the second time derivative is the acceleration $a = \ddot{a}\chi$. Since ä equals as follows:

$$\ddot{a} = \frac{d^2a}{dt^2}$$

we get as the acceleration a:

$$a = \frac{d^2a}{dt^2}\chi = \frac{d^2R}{dt^2}$$

In case of speed v, it is a single derivative with respect to time:

$$v = \frac{dR}{dt}$$

and if there is no derivative at all, then $R = R$.

The time coordinate in Robertson-Walker metrics, t, is the lifetime of the universe, K is a constant associated with curved space, and a(t) is a function of time that depends on the expansion or eventual contraction of the universe. The distance between two points in space (that is, the "size" of the universe) is indicated by s, the value of which changes in time t. The metric also depends on the value of the constant K, i.e. the curvature of space - whether it is flat, negative or positive curvature of the space of the universe. The latter equation, called the Robertson-Walker metric, tells us the cosmological future of the expanding universe. It depends on whether the space of the universe is generally flat, positive or negative.

Based on the Robertson-Walker metrics describing expanding space

$$(ds)^2 = c^2dt^2 - (dl_k)^2$$

but not from the Riemann´i metrics:

$$(ds)^2 = \sum_{i=0}^{3} \sum_{k=0}^{3} g_{ik}(x)dx_i dx_k$$

in which $g_{ik} = g_{ki}$

$$g_{ik} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -r^2 & 0 \\ 0 & 0 & 0 & -r^2 sin^2\theta \end{pmatrix}$$

the components of the Albert Einstein’s tensor G_{il}, known from general relativity, are calculated from the Einstein’s equation:

$$G_{ik}(g(x)) = -\frac{8\pi G}{c^4}T_{ik}$$

in which g(x) is:

$$g(x) = g_{ik}(x)$$

Consequently, the components of the Einstein tensor contain a function a(t) that depends on time:

$$g_{ik} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & a(t) & 0 & 0 \\ 0 & 0 & a(t)sin\chi & 0 \\ 0 & 0 & 0 & a(t)sin\chi\ sin\,\theta \end{pmatrix}$$

This unknown function must be found in Einstein's equations. In cosmology, the function a(t) is the scale factor of the universe. Considering the cosmological principle, the components of the energy-momentum tensor should appear as follows for the given Robertson-Walker metric:

$$T_{00} = \rho c^2$$

$$T_{\alpha\alpha} = -p g_{\alpha\alpha}$$

in which α = 1, 2, 3, $T_{il} = 0$, if i ≠ l, i, l = 0, 1, 2, 3. $g_{\alpha\alpha}$ are the diagonal spatial components of the metric tensor, ρc^2 is the density of matter and energy in the universe, and p is the pressure. Since collisions between galaxies are extremely rare, the pressure p is zero. If the components of the Einstein tensor G_{il} and the energy-momentum tensor T_{il} found in the previously described way are put into Einstein's equations, then the well-known Friedmann equations are obtained, which are the basis of the entire modern cosmology doctrine:

$$\ddot{a} = -\frac{4\pi G a}{3}\left(\rho + \frac{3p}{c^2}\right)$$

$$\frac{1}{2}(\dot{a})^2 - \frac{4\pi G}{3}\rho a^2 = -\frac{kc^2}{2}$$

in which k = 1, 0, -1 and

$$\dot{a} = \frac{d}{dt}a(t)$$

$$\ddot{a} = \frac{d^2 a}{dt^2}$$

The latter mathematical equations show that the resulting relation (in case p = 0)

$$\ddot{a} = -\frac{4\pi G a}{3}\rho$$

actually exist in the equation

$$\frac{1}{2}\dot{a}^2 - \frac{4\pi G}{3}\rho a^2 = -\frac{kc^2}{2}$$

and therefore the latter equation can be written in the following form:

$$\frac{1}{2}\dot{a}^2 + \ddot{a}a = -\frac{kc^2}{2}$$

In the previously presented equations, a(t) is the scaling factor, $c^2\rho(t)$ is the matter-energy density, and p(t) is pressure.

1.8 Teleparallel theory of gravity

Since in reality the sources of gravitational field rotate (such as stars and planets), the following metric describes such a field:

$$ds^2 = g_{tt}dt^2 + 2g_{t\varphi}dtd\varphi + g_{\varphi\varphi}d\varphi^2 + g_{rr}dr^2 + g_{\theta\theta}d\theta^2$$

which takes into account the mass M and the angular momentum J of celestial bodies. In such a metric, the time t and the angular coordinate φ are related to each other due to $g_{t\varphi} \neq 0$. It is an "axisymmetric gravity field", in which the momentum of a moving body is as follows:

$$l = mg_{\varphi\mu}\dot{x}^\mu = m(g_{\varphi t}\dot{t} + g_{\varphi\varphi}\dot{\varphi})$$

However, for the Schwarzschild gravitational field, the following equation holds: $g_{t\varphi} = 0$, so we get:

$$l = mg_{\varphi\varphi}\dot{x}^\mu = mr^2\dot{\varphi} = mr^2\omega = mrv$$

The latter is the classical expression for angular momentum. If the components of the metric tensor $g_{\mu v}$ do not depend on the coordinate φ, then l is a constant when moving along the "geodetic line":

$$l = mg_{\varphi\mu}\dot{x}^\mu = m(g_{\varphi t}\dot{t} + g_{\varphi\varphi}\dot{\varphi})$$

If a body begins to fall towards the source of the gravitational field and the angular momentum of the body equals zero $l = 0$, then it is described in the general theory of relativity as follows:

$$\frac{\dot{\varphi}}{\dot{t}} = -\frac{g_{t\varphi}}{g_{\varphi\varphi}}$$

The rotational speed of a body around the source of the gravitational field relative to the distant observer is as follows:

$$\omega = \frac{d\varphi}{dt} = \frac{\dot{\varphi}}{\dot{t}} = -\frac{g_{t\varphi}}{g_{\varphi\varphi}} \neq 0$$

This means that a body falling towards the source of a gravitational field begins to revolve around the source with respect to a distant observer. Since the body's angular momentum is equal to zero $l = 0$, the body's ITS (i.e. the inertial background system of the body) starts to rotate as it approaches the source. This is called ITS “entrainment”, which is only inherent in spacetime with a rotating gravitational field source. In this case, the axis of the gyroscope starts to change its direction when revolving around the source.

The effect of entrainment of the inertial background system is inherent only to Albert Einstein's theory of general relativity, and therefore gravity must be considered and understood only from Einstein's theory of general relativity, and not through any other theories of gravity. For example, the teleparallel theory of gravity, which describes the warping of spacetime instead of its curvature, can no longer be considered.

For example, a gyroscope precesses a rotating gravitational field source when moving, which means that the axis of the gyroscope starts to change its direction when rotating around the source. This is called the ITS entrainment effect (since the body's ITS begins to rotate as it approaches the source), and such a phenomenon appeared with 99% accuracy in the Gravity Probe B experiment conducted in 2004-2005, during which the gyroscope moved around the Earth with a polar satellite. This experiment determined a change in the satellite's spin axis of 0.00184 degrees of arc per year and an entrainment of spacetime near the Earth, which changes the plane of rotation of the satellite relative to the plane of rotation of the Earth by 0.0000114 degrees per year.

1.9 Quantum field theory

1.9.1 Introduction

In the following, we present a brief overview of such physical and mathematical analysis that describes quantum electrodynamics. However, this is only a general description, since quantum electrodynamics contains very long various mathematical derivations and calculations. In the following, we will focus only on the most important points and basic concepts that ultimately led to the creation of quantum electrodynamics in the first half of the 20th century. Quantum electrodynamics was the first quantum field theory in the history of physics that attempted to describe the energy field using quanta.

1.9.2 Quantum field theory

In quantum mechanics, the state of a particle is described by the wave function Ψ.

> The square of the modulus of the wave function physically gives the probability per unit volume, i.e. the probability density for the location of any particle in the corresponding part of space. For stationary states, the shape of the wave function is determined such that the probability density no longer depends on time. The wave function and the square of its modulus are mathematically complex quantities. This means that probability can only be expressed as a real number.

All information must be obtained from this wave function with some mathematical operations. The basis of these mathematical operations are operators that transform one function into another. Operators are among the basic concepts of quantum mechanics, and therefore without them, neither the formalism nor the physical content of quantum mechanics can be understood. In mathematics, an operator is a rule that can be used to get from one function to another function. In quantum mechanics, only multiplication operators and differentiation operators are needed. Operators used in quantum mechanics are mostly linear. Multiplying operators means applying them sequentially, and therefore the order of operators in a multiplication is generally important. The result does not depend on the order in which the operators are applied when the operators commute with each other. The order in which the operators are applied is important in case of non-commuting operators. It should also be noted that operators always affect functions.

In quantum mechanics, each physical quantity (energy, momentum, etc.) corresponds to a specific operator. In order to obtain the operators of physical quantities, it is mostly necessary to know only the coordinate and momentum operators. The coordinate operators (in cross coordinates) are the corresponding coordinates themselves. These are the multiplication operators. However, in case of the impulse operator, it is already the product of multiplication operator and differentiation operator. Each physical quantity corresponds to a certain operator, and the eigenvalues of the operator give the measurable values of this physical quantity. The eigenvalues of physical operators must be real, not imaginary, because all physically measurable quantities are real. However, in quantum mechanics there are also such eigenvalues of linear operator that are not real. For a Hermitian operator, the co-operator is equal to the operator itself. The operators of physical quantities must be Hermitian in quantum mechanics, in which case its eigenvalues are real.

In quantum field theory, one goes from a classical field to a quantized field. This is called field quantization. In this case, the field potential is regarded as an operator acting on some kind of field function ϕ. For example, vacuum corresponds to a certain field function ϕ_0. Field potentials are quantized according to field operators. Field operators can be generalized coordinates and their corresponding generalized impulses. This is how commutation rules are postulated. The commutator of operators equals a number, no longer an operator. The so-called "secondary field quantization" consists in the fact that, by quantizing the field, the state functions that describe the continuous fields are in turn transformed into operators. A scalar state function describes particles with spin 0.

The electromagnetic field potential known from classical electrodynamics is a four-dimensional vector potential $A_\mu(x)$ that satisfies Maxwell's equations.

Electron-positron field theory postulates that the components of the field potential corresponding to the particles satisfy the same equations as the wave functions of the particles. For example, in case of a relativistic electron, this is the Dirac equation. Anticommutation relations, not commutation relations, apply between electron-positron field operators. Nevertheless, anticommutation connections are generally also often referred to as commutation connections.

The Pauli’s exclusion principle in quantum physics means that there can only be one electron with the same momentum and polarization. This leads to Fermi-Dirac statistics. Pauli's prohibition also emerges from quantization with anticommutators. The field cannot be quantized when applying the anticommutation rule to particles with half-number spin, because then a contradiction with the Pauli prohibition appears. However, if you quantize with commutators for particles with integer spin, the Pauli prohibition does not arise and therefore does not contradict it. Such particles obey Bose-Einstein statistics.

After long mathematical operations and transformations, the operators c and c* are obtained, which can be interpreted as the creation and disappearance operators of the corresponding quanta (i.e. photons). It should also be mentioned that the commutators of field operators A are also regular functions, not operators anymore.

The equations also reveal that the anticommutators of the electron-positron field are actually ordinary functions. After mathematical operations and transformations, operators are obtained that describe the creation of an electron (with the corresponding polarization and momentum), i.e., the electron creation operator, the electron loss operator, the positron creation operator, and the positron loss operator.

During the interaction between the electron-positron field and the electromagnetic field, energy is transferred from one field to the other with the creation and loss of corresponding quanta. Fields undergo changes due to this interaction. The interaction occurs when the points of the quantum spacetime coincide in different fields, i.e. when the quanta (i.e. particles) meet. The strength of the interaction is determined by the electron's charge e.

The energy of a quantum system is described by the Hamiltonian H. The Schrödinger equation is the fundamental equation of quantum mechanics. According to this, the Hamiltonian describes the temporal evolution of the quantum system. For the state functions given in the Schrödinger representation, the wave function is described by the Schrödinger equation. However, in Heisenberg's representation, the state functions are time invariant, but the time evolution is described by operators. This is actually essentially the same as Schrödinger's representation. In quantum field theory, however, an interaction representation is used, in which the time evolution of the state function depends only on the interaction Hamiltonian, not on the Hamiltonian of free fields. The Hamiltonian itself consists of a free-field Hamiltonian and an interaction Hamiltonian. The field vector includes the electron-positron and electromagnetic fields. The change of the field vector is described by some kind of operator S, which is also represented as a matrix equation. This is called the scatter matrix, or S-matrix. Different quantum states at different moments of time are connected by some element of the S-matrix. The transition probability of the corresponding quantum state can be calculated if the value of the corresponding matrix element is known.

In chronological multiplication, all field operators are ordered in descending order of time. However, in quantum electrodynamics, the normal order is used instead, in which all creation operators are placed to the left of the decay operators. Thus, the vacuum energy and momentum are equal to zero.

According to the quantum field theory, vacuum polarization consists in the fact that the charge of an electron creates intense processes in the space around it, i.e. in vacuum, due to the action of virtual particles. In the space surrounding an electron's negative charge, positive charges generally organize closer to the electron, while negative charges organize further away.

An electromagnetic wave (for example, a light wave) is not actually continuous, but moves through space in "portions", or quanta. According to the laws of quantum electrodynamics, or quantum field theory, electromagnetic field can also be viewed as a collection of virtual photons or a stream of them. The interaction between electrically charged particles actually consists in one particle absorbing one of the photons emitted by the first. This means that charged particles exchange photons with each other. Each charged particle creates a field around itself, which actually consists of emitting and absorbing photons. However, these photons are not real, but are understood as virtual. These virtual particles cannot be detected while they exist. This is what makes them virtual. Usually, the sum of energies of a photon and a charged particle is greater than that of a stationary charged particle (the photon itself has no charge). However, this violates the law of conservation of energy. However, if a photon emitted by a charged particle is absorbed by the same or another charged particle before the time interval

$$\Delta t = \frac{h}{\Delta E}$$

passes, then it is not possible to detect a violation of the law of conservation of energy. ΔE indicates the energy deviation from the value determined by the pulse

$$E^2 = p^2c^2 + m^2c^4$$

A real photon, which can be emitted, for example, when two charged particles collide, can exist for an unlimited time. Between two points in space with a distance of $l = c\Delta t$, a virtual photon can interact within Δt. The radius of influence of electromagnetic forces can be indefinitely large, because the energy of a photon

$$E = hf = mc^2$$

can be indefinitely small. Light particles, or photons, are described by the quantum energy equation $E = hf = mc^2$, where f is the wave frequency and h is Planck's constant with a value of $6{,}62 * 10^{-34}$ Js.

The particles mediating the field are not real but virtual, because they carry energy and momentum independently. An electron can carry energy that is less than its rest mass. The impulse that is currently being transferred may not be directed from the point of origin to the point of absorption. A virtual photon can also have a longitudinal polarization component. That is why these particles are unreal, and that is why they are called virtual particles. It is not possible to prove their existence experimentally.

In quantum mechanics, the dimensions of a photon as a particle are not described, but instead the motion of particles in time and space is described by a wave function. One of the basic equations of quantum mechanics, λ=h/p or λ=h/mv, simultaneously shows the length of a wave function and the length of a light wave, or an electromagnetic wave. This physically means that the incident wave of a photon is actually a light wave or an electromagnetic wave. De Broglie's equation λ=h/mv=h/p relates the wave properties (λ) and corpuscular properties (m, v, p) of particles.

The relationship between a photon and a light wave is analogous to the relationship between the wave function known in quantum mechanics and the particle it describes. For example, the probability with which a photon gets to a certain point in space is determined by the square of the amplitude of a light wave, in the same way that the intensity of light is measured by the mean value of the square of an electric vector of a light wave. In exactly the same way, the square of the modulus of a wave function physically gives the probability per volume unit, i.e. the probability density for the location of any particle in the corresponding part of space. In stationary states, the shape of the wave function is determined such that the probability density of the particle no longer depends on time. The wave function and the square of its modulus are mathematically complex quantities. This means that probability can only be expressed as a real number. All of the above essentially means that quantum mechanics does not allow determining the exact location of a particle in space or its trajectory, but it is only possible to predict the probability of finding a particle at a certain point in space. Thus, quantum mechanics has a statistical character.

For example, the uncertainty in the position of an electron in a hydrogen atom is almost equal to the atomic radius. Therefore, an electron cannot be viewed as a particle moving along a fixed trajectory, but rather as a cloud of electrons around the hydrogen nucleus.

Quantum mechanics does not actually provide information about the size of a photon as a particle, but predicts at which point in space and time we can find the particle. This means that instead of a particle's size and exact location in spacetime, there is actually a probability field described by the well-known wave function. For example, the wave function of light, or a photon

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

is a light wave, or an electromagnetic wave. Waves that determine the probability of finding particles are called de Broglie' waves for short. A function that describes waves, i.e. a mathematical expression that describes the specific shape of probability waves in space and changes over time is called a wave function.

1.9.3 Mathematical analysis

The equations known as Maxwell's equations are derived in quantum electrodynamics from the Lagrangian L of the electromagnetic field:

$$L = -\frac{1}{4} F_{\mu\nu} F_{\mu\nu}$$

and the general solution of these equations is:

$$A_\mu(\vec{k}, x) = c_\mu(\vec{k}) e^{ikx} + c^*{}_\mu(\vec{k}) e^{-ikx}$$

The product kx represents a four-dimensional scalar product:

$$kx = \vec{k}\vec{r} + \omega_k x_4$$

and the possible polarization states are numbered by the subscript μ. A, c, and c* become operators upon quantization. The general solution must also be consistent with the postulated commutation rules:

$$[c, c] = [c^*, c^*] = 0$$

$$\left[c_\mu\left(\vec{k}\right), c^*{}_v\left(\overrightarrow{k`}\right)\right] = \delta_{\mu v}\delta\left(\vec{k} - \overrightarrow{k`}\right)$$

Here, the operators c and c* are interpreted as creation and destruction operators of quanta or photons, respectively. The commutators of the energy field operators A are now regular functions, no longer operators. This is due to commutation rules.

The energy of a quantum system is described by the Hamiltonian H:

$$\widehat{H} = -\frac{h^2}{2M}\Delta + U(\vec{r})$$

The Schrödinger equation is the fundamental equation of quantum mechanics. According to this, the Hamiltonian describes the temporal evolution of the quantum system. For the state functions given in the Schrödinger representation, the wave function is described by the Schrödinger equation:

$$ih\frac{\partial\psi(\vec{r},t)}{\partial t} = -\frac{h^2}{2M}\left(\frac{\partial^2\psi(\vec{r},t)}{\partial x^2} + \frac{\partial^2\psi(\vec{r},t)}{\partial y^2} + \frac{\partial^2\psi(\vec{r},t)}{\partial z^2}\right) + U(\vec{r},t)\psi(\vec{r},t)$$

However, in Heisenberg's representation, the state functions are time invariant, but the time evolution is described by operators. This is actually essentially the same as Schrödinger's representation. In quantum electrodynamics, or KED, the state evolution depends only on the interaction Hamiltonian:

$$i\frac{\partial\Phi}{\partial t} = H'\Phi$$

no longer from the free-field Hamiltonian. Such a representation is called an "interaction representation". The Hamiltonian itself consists of a free-field Hamiltonian and an interaction Hamiltonian. The field vector is Φ, which includes all fields, but primarily electron-positron and electromagnetic fields. Due to the interaction, Φ changes from the state (0) at time t = 0 to the state (t) at time t. Such a change is described by the operator S, which is expressed as a matrix:

$$\left(\Phi(t)\right) = (S(t,0)(\Phi(0))$$

It is a scattering matrix, or S-matrix, which is called "Streuung" in German. The operator S transforms the vector of all possible states (0) into a new vector of all possible states (t). Different quantum states at different moments of time are connected by some element of the S-matrix. The transition probability of the corresponding quantum state can be calculated if the value of the corresponding matrix element is known. If we put the S-matrix into the interaction Hamiltonian equation, we get:

$$i\frac{\partial S}{\partial t}\Phi(0) = H'S\Phi(0)$$

or

$$i\frac{\partial S}{\partial t} = H'S$$

Since the correlation constant e is a number less than one:

$$e = \sqrt{\alpha} << 1$$

where

$$\alpha = \frac{e^2}{4\pi\varepsilon_0 hc} \approx \frac{1}{137}$$

then the S-matrix is developed in rows according to the powers of the correlation constant e:

$$S(t, t_0) = \sum_{k=0}^{\infty} S_k(t, t_0)$$

The very first "approximation" would be S_0, since it has the highest probability. This means that there is no reaction. Therefore $S_0 = 1$. The other members are "gradually" e^k times smaller. Likewise, H' is also small to the order of e. In case of equalization of the terms of the corresponding order in the equation:

$$i\frac{\partial S}{\partial t} = H'S$$

the following is obtained:

$$i\frac{\partial S_k}{\partial t} = H'S_{k-1}$$

the integration of which gives the result:

$$S_k(t, t_0) = i\int_{t_0}^{t} H'(\tau)S_{k-1}(\tau, t_0)d\tau$$

In this case, we can view the members sequentially, where the integration variables are denoted in order $t_1, t_2, \ldots$:

$$S_k(t, t_0) = (-i)^k \int_{t_0}^{t} dt_1 \int_{t_0}^{t_1} dt_2 \ldots \int_{t_0}^{t_{k-1}} dt_k\, H'(t_1)H'(t_2) \ldots H'(t_k)$$

The values of the integration variables are ordered:

$$t \geq t_1 \geq t_2 \geq \cdots \geq t_k$$

The H's are arranged in a "chronological product" in the product of H's. The integration volume would increase by k! times when the upper paths of the integrals are equalized:

$$S_k(t, t_0) = \frac{(-i)^k}{k!} \int_{t_0}^{t} dt_1 \int_{t_0}^{t} dt_2 \ldots \int_{t_0}^{t} dt_k\, T(H'(t_1)H'(t_2) \ldots H'(t_k))$$

In the latter, T stands for chronological multiplication, and this means that the chronological order applies in the multiplication. In case of chronological multiplication:

$$S_k(t,t_0) = \frac{(-i)^k}{k!}\int_{t_0}^{t} dt_1 \int_{t_0}^{t} dt_2 \dots \int_{t_0}^{t} dt_k\, T(H`(t_1)H`(t_2)\dots H`(t_k))$$

all field operators are sorted in descending order of time:

$$t \geq t_1 \geq t_2 \geq \cdots \geq t_k$$

During the interaction between the electron-positron field and the electromagnetic field, energy is transferred from one field to the other with the creation and loss of corresponding quanta. Fields undergo changes due to this interaction. The interaction occurs when the points of the quantum spacetime coincide in different fields, i.e. when the quanta (i.e. particles) meet. The strength of the interaction is determined by the electron's charge e. In quantum electrodynamics, the Lagrangian of the electron-positron field is considered:

$$L = -\frac{1}{2}\left(\bar{\psi} y_v \frac{\partial \psi}{\partial x_v} - \frac{\partial \bar{\psi}}{\partial x_v} y_v \psi\right) - m\bar{\psi}\psi$$

as well as with the Lagrangian of the electromagnetic field:

$$L = -\frac{1}{4} F_{\mu v} F_{\mu v}$$

Apart from these two, the "interaction Lagrangian" is also considered:

$$L = L_{e-m} + L_{e-p} + L'$$

the form of which is:

$$L` = e\bar{\psi} y_\mu \psi A_\mu$$

It refers to “flow” as:

$$j_\mu = \bar{\psi} y_\mu \psi$$

Using the equation for the interaction Hamiltonian:

$$S(t,t_0) = \sum_{k=0}^{\infty} S_k(t,t_0)$$

we can calculate the interaction Lagrangian as follows:

$$H' = \frac{\partial L'}{\partial \frac{\partial u_A}{\partial x_0}} \frac{\partial u_A}{\partial x_0} - L'$$

where

$$u_A = \bar{\psi}, \psi, A_\mu$$

However, the equation still takes this form:

$$H' = -L'$$

since L' contains no derivatives. If we place the equation for the interaction Hamiltonian:

$$H' = -L'$$

and the equation for the interaction Lagrangian:

$$L` = e\bar{\psi}y_{\mu}\psi A_{\mu}$$

into the S-matrix:

$$S_k(t,t_0) = \frac{(-i)^k}{k!}\int_{t_0}^{t} dt_1 \int_{t_0}^{t} dt_2 \dots \int_{t_0}^{t} dt_k \, T(H'(t_1)H'(t_2) \dots H'(t_k))$$

it appears that all field operators must be ordered in descending order of time. Operators are bound in threes to the same point in space. You have to integrate over these points. However, since the energy and momentum of vacuum must be equal to zero, all creation operators must therefore be placed to the left of the loss operators. This is called normal sequence, or normal multiplication. For example, if we apply energy operators

$$E = P_0 = -iP_4 = \frac{1}{2}\sum_{\vec{k}} k_0 \, (c_k c_k^* - c_k^* c_k)$$

and impulse operators

$$\vec{P} = \frac{1}{2}\sum_{\vec{k}} \vec{k} \, (c_k c_k^* - c_k^* c_k)$$

to vacuum state Φ_0, we get:

$$P_0\Phi_0 = \vec{P}\Phi_0 = 0$$

This is only true when we take, instead of energy

$$E = P_0 = -iP_4 = \frac{1}{2}\sum_{\vec{k}} k_0 \, (c_k c_k^* - c_k^* c_k)$$

and impulse

$$\vec{P} = \frac{1}{2}\sum_{\vec{k}} \vec{k} \, (c_k c_k^* - c_k^* c_k)$$

the following expressions:

$$P_0 = \sum_{\vec{k}} k_0 \, c^* c$$

$$\vec{P} = \sum_{\vec{k}} \vec{k} \, c^* c$$

since $c^*\Phi_0 = \Phi_1$, $c^*c^*\Phi_0 = \Phi_2$, ... , $c\Phi_0 = 0$. The same order must apply in the equation for the S-matrix, but it instead has a chronological order:

$$S_k(t,t_0) = \frac{(-i)^k}{k!}\int_{t_0}^{t} dt_1 \int_{t_0}^{t} dt_2 \dots \int_{t_0}^{t} dt_k \, T(H'(t_1)H'(t_2) \dots H'(t_k))$$

To do this, we express a chronological product:

$$T(uv) =: uv: + \dot{u}\dot{v}$$

where u and v are arbitrary operators, : : denotes the normal product and $\dot{u}\dot{v}$ is called the “chronological relation”, which is defined as follows:

$$\dot{u}(t_1)\dot{v}(t_2) = \begin{cases} [\, u^-(t_1)v^+(t_2)\,], & kui \;\; t_1 > t_2 \\ [\, v^-(t_2)u^+(t_1)\,], & kui \;\; t_1 < t_2 \end{cases}$$

In it, u+ and v+ represent the part with creation operators and u- and v- represent the part with loss operators:

$$u = u^+ + u^-$$

and

$$v = v^+ + v^-$$

Due to the commutation relations:

$$\{a_r(p), a^*{}_s(p`)\} = \delta_{rs}\delta_{\vec{p},\vec{p}`}$$

$$\{b_r(p), b^*{}_s(p`)\} = \delta_{rs}\delta_{\vec{p},\vec{p}`}$$

$$\{a.b\} = \{a, b^*\} = \{a^*, b\} = \{a^*, b^*\} = 0$$

and

$$[c, c] = [c^*, c^*] = 0$$

$$\left[c_\mu(\vec{k}), c^*{}_v(\vec{k`})\right] = \delta_{\mu v}\delta(\vec{k} - \vec{k`})$$

chronological relation expressions are actually regular functions, not operators. That is why the above multiplication:

$$T(uv) =: uv: + \dot{u}\dot{v}$$

allows preservation of normal products in the S-matrix. For example, any T product can now be expressed as a sum of normal products:

$$T(u_1u_2u_3u_4) =: u_1u_2u_3u_4: + \dot{u}_1\dot{u}_2: u_3u_4: +: \dot{u}_1u_2\dot{u}_3u_4: + \cdots + (\dot{u}_1\dot{u}_2)(\dot{u}_3\dot{u}_4) + \cdots$$

in the members of which there are all sorts of connections. In quantum electrodynamics, such expressions of chronological relationships occur, for example:

$$\dot{A}_\mu(x)\dot{A}_v(y) = \delta_{\mu v}\frac{-i}{(2\pi)^4}\int_C d^4p\,\frac{e^{ip(x-y)}}{p^2}$$

and

$$\dot{\psi}_\alpha(x)\dot{\bar{\psi}}(y) = \frac{1}{(2\pi)^4}\int_C d^4p\,\frac{(p_\mu y_\mu - m)_{\alpha\beta}}{p^2 - m^2}$$

In it, the integration path C encloses the left side of the complex plane

$$Re\; p_0 < 0$$

if $x_0 < 0$. If $x_0 > 0$, then the right side. All other chronological relationships between field operators are equal to zero.

In the expression for S_k, there are several summands after

$$T(u_1u_2u_3u_4) =: u_1u_2u_3u_4: + \dot{u}_1\dot{u}_2: u_3u_4: +: \dot{u}_1u_2\dot{u}_3u_4: + \cdots + (\dot{u}_1\dot{u}_2)(\dot{u}_3\dot{u}_4) + \cdots$$

each of which has k spacetime coordinates. Integration takes place over them. There are a different number of connections between these points in addendum:

$$\dot{A}_\mu(x)\dot{A}_v(y) = \delta_{\mu v}\frac{-i}{(2\pi)^4}\int_C d^4p\frac{e^{ip(x-y)}}{p^2}$$

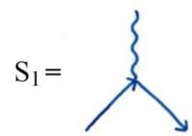
and

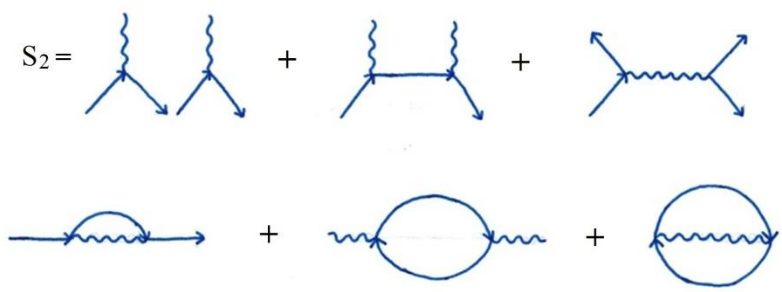
$$\dot{\psi}_\alpha(x)\dot{\bar{\psi}}(y) = \frac{1}{(2\pi)^4}\int_C d^4p\frac{(p_\mu y_\mu - m)_{\alpha\beta}}{p^2 - m^2}$$

In addition, there are also a varying number of unaffiliated field operators:

$$A_\mu(x), \psi(x), \bar{\psi}(x)$$

In the following, the coordinate x is denoted by a point; the relation $\dot{A}_\mu(x)\dot{A}_v(y)$ with the wavy line between the points x and y; the relationship $\dot{\psi}(x)\dot{\bar{\psi}}(y)$ with the directed (arrowed) line between the corresponding points; the free operator A_μ with the wavy line connected to the point and ψ and $\bar{\psi}$ with the line entering and leaving the point, respectively. Because of all this, we would get the following graphs for S_1 and S_2:



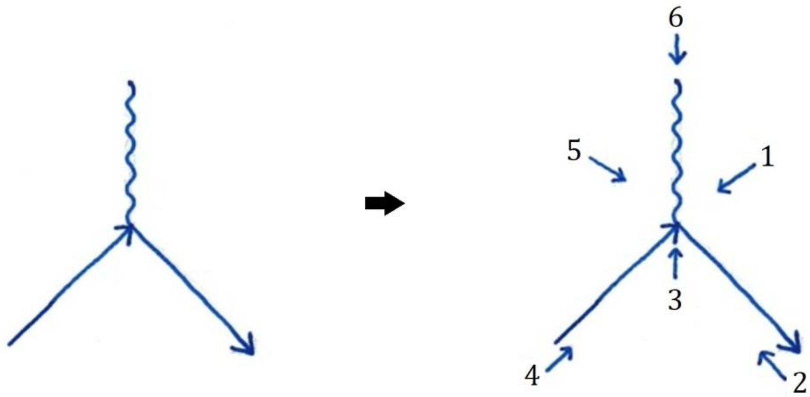


S_3 contains many more members.

These are "Feynman graphs". The coordinates are represented by points, or "vertices of the graph", which are integrated over infinite spacetime. Each vertex of the graph has one incoming and one outgoing electron-positron line. In addition, there is also a single photon line. Since the lines are classified as internal and external, therefore the lines entering and exiting the reaction are denoted by external lines. For example, an electron can move in the direction of the arrow, but a positron therefore moves in the opposite direction. Graphs actually have several possibilities of interpretation. However, for further analysis, let's look at the following "elementary graph":

$$S_1 = ie\int d^4x\colon\bar{\psi}(x)y_\mu A_\mu\,(x)\psi(x)\colon.$$

the graph of which is:



The figure describes 6 different processes that can depend on the direction of time:

1. a positron absorbs a photon,
2. a positron emits a photon,
3. annihilation of the pair,
4. an electron emits a photon,
5. an electron absorbs a photon,
6. formation of a pair.

Starting from S_2, the graphs have internal lines in addition to external lines. They are interpreted as non-real particles because they carry energy and momentum independently. An inner-line electron can have an energy even smaller than its rest mass. The transmitted pulse is generally not directed from the point of origin to the point of absorption. A real photon does not have a "longitudinal polarization component", but the photon on the inner line of the graphs does. Because of all this, these unreal particles are called "virtual". It is not possible to detect their existence, but the time Δt of the existence of these particles is determined by the Heisenberg uncertainty relation:

$$\Delta t \Delta E \geq h$$

where ΔE shows the energy of a particle:

$$E^2 = p^2c^2 + m^2c^4$$

The number of vertices on the Feynman graph is equal to the order number k of the process, which is also in the exponent of the correlation constant:

$$S_k(t, t_0) = \frac{(-i)^k}{k!} \int_{t_0}^{t} dt_1 \int_{t_0}^{t} dt_2 \ldots \int_{t_0}^{t} dt_k \, T(H'(t_1)H'(t_2) \ldots H'(t_k))$$

Therefore, each subsequent S_k is $\frac{1}{e}$ times smaller than the previous one. Depending on the accuracy, it is possible to limit the calculations to a few S_k. Each subsequent term represents a small correction to the previous calculation and is called a “perturbation calculation”.

The supply of outer lines determines the process and the number of inner lines is not limited. For example, the matrix element of such a graph, which describes the scattering of an electron on an electron, contains any higher-order terms (as well as vacuum "fluctuations"). One has to integrate over all possible values of energy and momentum and therefore infinite paths appear. This means that the closed loops of the graph correspond to "undefined integrals" that do not converge. Therefore, dispersions occur in higher order processes. The solution of diffuse integrals consists in "renormalization". When applying quantum electrodynamics, so-called "vacuum corrections" resulting from renormalization must be added to the calculation results obtained with the first orders.

A phenomenon called "vacuum polarization" physically explains this mutual retraction of infinities. According to the quantum field theory, vacuum polarization consists in the fact that the charge of an electron creates intense processes in the space around it, i.e. in vacuum, due to the action of virtual particles. In space around an electron's negative charge, positive charges generally organize closer to the electron, while negative charges organize further away. Because of this, the positive charges shield the electron's actual charge, and thus the electron's charge appears to be smaller at a distance.

The dissipative integrals of quantum electrodynamics give infinitely large values for the vacuum energy and mass density. However, renormalization gives them a value of zero, since anywhere on the energy scale we can count the value as zero. The energy level that fills the entire room evenly is not manifested in reality. Renormalization allows the dispersions or infinities that appear in quantum electrodynamics to be compensated without contradictions, i.e. the theory can be renormalized by re-evaluating the constants, because there are peaks associated with three lines in the Feynman graphs, and the photon line corresponds to a particle with zero rest mass.

According to quantum field theory, the entire vacuum of the universe is full of virtual particles, and therefore vacuum actually has an infinitely high energy density. However, as a result of renormalization, we can still consider the energy density of this vacuum to be practically zero, because such an energy level, which uniformly fills the entire space of our universe, is not actually manifested or measurable in any way. We can define the value 0 anywhere on the energy scale.

1.10 The nature of quantum gravity

The fields that mediate the electromagnetic, weak and strong interactions are all energy fields. Likewise, the Higgs field is also an energy field. The field has energy. However, gravitational field is not an energy field, because the force of gravity results from the curvature of spacetime. A gravitational field does not have energy, but a body can have potential energy while in a gravitational field. Since the gravitational field is not an energy field, there cannot be such particles or "gravitons" that would mediate the gravitational interaction. Gravitational interaction is mediated only by the curvature of spacetime. Gravitons therefore cannot exist. From this follows the fact that there are two types of fields in the universe: one type is energy fields, and the other is the kind of fields that are "caused" by the curvature of spacetime.

The physical laws of the universe start to apply only from the "Planck length" scale:

$$l = 1{,}616\ 229(38) * 10^{-35}\ m$$

Absolutely no known particle could fit into a volume the diameter of a Planck length. The same principle actually applies to time, where the smallest possible period of time corresponds to the "Planck time" t:

$$t = 5{,}39121 * 10^{-44}\ s$$

This means that in the range of space dimensions:

$$0 \dots 10^{-35}\ m$$

and in time periods ranging between:

$$0 \ldots 10^{-44}\ s$$

makes absolutely no sense physically, but only makes mathematical sense.

Since the smallest possible "length of space" in the universe can only be the Planck length l, therefore the gravitational space contraction equation cannot be equal zero:

$$l = l_0\sqrt{1-\frac{R}{r}} \neq l_0\sqrt{1-\frac{R}{R}} = 0$$

The ratio of the radii R and r cannot be equal to one:

$$\frac{R}{r} \neq \frac{R}{R} = 1$$

since nothing can be "smaller" than the Planck length l:

$$\frac{R}{r} \geq l$$

A similar principle applies to the gravitational time dilation equation:

$$t` = \frac{t}{\sqrt{1-\frac{R}{r}}} \neq \frac{t}{\sqrt{1-\frac{R}{R}}} = \infty$$

where t is, for example, the Planck time. The physical content is that 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, immediately manifests itself:

> This means that the distance between two points in space can only decrease up to the Planck length l, after which the distance between two points in space becomes zero "instantly". However, at the same time, the distances between spatial points and time periods can be infinitely large.

The sudden transition to the infinite curvature of spacetime on an extremely small scale of spacetime (i.e. the Planck length l) is the main content of this quantum gravity theory.

Similar to gravitational space contraction and gravitational time dilation, exactly the same physical principle applies to kinematic (i.e. caused by motion) space contraction:

$$l = l_0\sqrt{1-\frac{v^2}{c^2}} \neq l_0\sqrt{1-\frac{c^2}{c^2}} = 0 = \frac{1}{\infty}$$

in which the following cannot hold:

$$\frac{v^2}{c^2} \neq 1$$

and for kinematic time dilation:

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

where the following equation cannot hold:

$$t = t`\sqrt{1-\frac{v^2}{c^2}} \neq \infty * \sqrt{1-\frac{c^2}{c^2}} = t = 0$$

or

$$\frac{v^2}{c^2} \neq 1$$

Physically, this means that upon reaching a certain speed, which is probably slightly less than the speed of light c in vacuum, time and space will change exponentially, i.e. immediately to infinity, if the speed increases in the future, and the numerical value of the speed will also immediately change to speed c.

1.11 Possibilities for interpretation of the quantum gravity field

Physical fields are often represented in coordinates by continuous functions. Since at every point in space the field "point" can change arbitrarily without violating the requirements of continuity, thus such a system has an infinite number of degrees of freedom. These field values are treated as "generalized coordinates" in field theories. The generalized coordinates of the field are the field potentials. Field potential

$$(A = 1,2,\dots,n)$$

and an n-component function

$$u_A(x)$$

describe a physical field in which x represents the spacetime coordinates x_μ:

$$(\mu = 1,2,3,4)$$

To avoid infinite values, every point in space must have a calculable energy density, understood as the "Lagrangian density". Nevertheless, terms such as "Hamiltonian" and "Lagrangian" are used.

In quantum field theory, a wave equation is derived that describes the physical nature and existence of a field particle in spacetime and its relation to the field potential φ. In quantum field theory, this is called field quantization, in which one switches from a classical field to a quantized field. In this case, in the quantum theory of fields, the field potential is considered an operator that acts on some kind of field function ϕ. For example, vacuum corresponds to a certain field function ϕ_0. Field potentials are quantized according to field operators. Field operators can be generalized coordinates and their corresponding generalized impulses. This is how the commutation rules are postulated:

$$[u_A, u_B] = [\pi_A, \pi_B] = 0$$

$$[u_A(\vec{r},t),\pi_B(\vec{r}`,t)] = i\delta_{AB}\delta(\vec{r}-\vec{r}`)$$

The commutator of operators is equivalent to a number in quantum field theory, no longer an operator. The so-called "*secondary field quantization*" consists in the fact that, by quantizing the field, the state functions that describe the continuous fields are in turn transformed into operators. For example, a scalar state function describes particles with spin 0.

The following form of the quantum mechanical momentum P operator was used to develop the quantum field theory:

$$-i\left[\hat{P}_\mu,\hat{\varphi}(x)\right] = \frac{\partial\hat{\varphi}(x)}{\partial x_\mu}$$

The latter equation shows that the impulse P, or the 4-impulse

$$p_\mu = P_\mu = mv_\mu = m\frac{dx_\mu}{d\tau} = m\frac{dx_\mu}{dt\sqrt{1-\beta^2}} = m\frac{dx_\mu}{dt\sqrt{1-\frac{v^2}{c^2}}}$$

a commutator with an energy field potential φ(x) must give a derivative of the field potential. However, if φ(x) is expressed as a superposition equation with the field potential in a 4-impulse commutator:

$$\varphi(x) = \frac{1}{\sqrt{V}}\sum_{\vec{k}}\frac{1}{\sqrt{2k_0}}\left(c(\vec{k})e^{ikx} - c^*(\vec{k})e^{-ikx}\right)$$

then the following very important relations are obtained:

$$-\vec{k}c_k = \left[\vec{P},c_k\right]$$

$$-k_0c_k = [P_0,c_k]$$

$$\vec{k}c^*{}_k = \left[\vec{P},c^*{}_k\right]$$

$$\vec{k}c^*{}_k = [P_0,c^*{}_k]$$

The validity of these connections must be in accordance with the so-called "commutation rules":

$$[c_k,c_{k`}] = [c^*{}_k,c^*{}_{k`}] = 0$$

$$[c_k,c^*{}_{k`}] = \delta_{\vec{k},\vec{k`}}$$

From the "eigenvalue problem" of energy and momentum:

$$P_0\Phi_\varepsilon = \varepsilon\Phi_\varepsilon$$

$$\vec{P}\Phi_\varepsilon = \vec{p}\Phi_\varepsilon$$

functions corresponding to the state of some field are found:

$$c_k\Phi_\varepsilon = \Phi_\varepsilon{}'$$

$$c_k^* \Phi_\varepsilon = \Phi_\varepsilon''$$

Using the above relations:

$$-\vec{k} c_k = [\vec{P}, c_k]$$

$$-k_0 c_k = [P_0, c_k]$$

$$\vec{k} c^*{}_k = [\vec{P}, c^*{}_k]$$

$$\vec{k} c^*{}_k = [P_0, c^*{}_k]$$

the following results are obtained:

$$P_0 \Phi_\varepsilon^{'} = P_0 c_k \Phi_\varepsilon = c_k P_0 \Phi_\varepsilon - k_0 c_k \Phi_\varepsilon = (\varepsilon - k_0)\Phi_\varepsilon{}'$$

$$P_0 \Phi_\varepsilon^{''} = P_0 c_k^* \Phi_\varepsilon = c_k^* P_0 \Phi_\varepsilon + k_0 c_k^* \Phi_\varepsilon = (\varepsilon + k_0)\Phi_\varepsilon{}''$$

Apart from them, the analogous impulse eigenvalue function $\vec{P}$ is also obtained. The effect of the operator c_k can be seen in the decrease of the energy and momentum of the field by $(k_0, \vec{k})$, but the increase of the energy and momentum of the field from the original by $(k_0, \vec{k})$ can only be effected by the operator c_k^*. That is why the operator c_k^* is called the quantum generation operator, i.e. the radiation operator with energy k_0 and momentum $\vec{k}$. Accordingly, c_k is the quantum vanishing operator or absorption operator. In case of vacuum Φ_0, the 1-particle state $c^*\Phi_0 = \Phi_1$, the 2-particle state $c^*c^*\Phi_0 = \Phi_2$, ... , and in the absence of the state $c\Phi_0 = 0$. The number of particles operator is $N_k = c_k^* c_k$. Using "commutation rules":

$$[c_k, c_{k`}] = [c^*{}_k, c^*{}_{k`}] = 0$$

$$[c_k, c^*{}_{k`}] = \delta_{\vec{k}, \vec{k`}}$$

is obtained in the following way:

$$N\Phi_0 = c^* c_0 \Phi_0 = c^* * 0\Phi_0 = 0 * \Phi_0$$

$$N\Phi_1 = Nc^*\Phi_0 = c^* c c^* \Phi_0 = c^*(1 + c^* c)\Phi_0 = c^*\Phi_0 = \Phi_1$$

According to this, the following rule applies: $cc^* - c^*c = 1$ or $cc^* = 1 + c^*c$. Further, the following is obtained:

$$N\Phi_2 = 2\Phi_2, \Phi_3 = 3\Phi_3, \ldots, N\Phi_n = n\Phi_n$$

In case of field quantization, the field potential is regarded as an operator acting on some kind of field function ϕ. Field potentials are quantized according to field operators. Field operators can be generalized coordinates and their corresponding generalized impulses. However, quantization, which has been successfully done in case of an electromagnetic field, for example, cannot be done in case of a gravitational field.

> The fields that mediate the electromagnetic, weak and strong interactions are all energy fields. Likewise, the Higgs field is also an energy field. The field has energy. However, gravitational field is not an energy field, because the force of gravity comes from the curvature of spacetime. A gravitational field does not have energy, but a body can have potential energy while in a gravitational field. Since the gravitational field is not an energy field, there can be no such particles or "gravitons" that mediate the gravitational interaction in the same way that photons do

in case of electromagnetic interaction. Gravitational interaction is mediated only by the curvature of spacetime.

The mathematical apparatus of quantum mechanics cannot be applied in case of a gravitational field, since the force of gravity is due to the curvature of spacetime, not the properties of an energy field. Therefore, in case of quantization of a gravitational field, the field potential cannot be considered as an operator that would act on some kind of field function ϕ. Field potentials are quantized according to field operators. The operators of an energy field can be generalized coordinates and their corresponding generalized impulses, but such an analogy cannot be applied to gravitational field, since it is no longer an energy field.

The equality of the equations of the gravitational potential U and the kinetic energy E_k is very important for understanding a quantum gravitational field:

$$U = \frac{GMm}{R} = \frac{mv^2}{2} = E_k$$

or

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

It is actually much more important than it has been thought until now. We will show this briefly as follows. For example, if in this equation, the speed equals the speed of light c:

$$v^2 = c^2$$

then we can derive the equation for the Schwarzschild radius R:

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

It shows the size of the Schwarzschild surface in spacetime that exists at the center of each black hole. However, at the same time, in the equation:

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

the expression of quantum energy can also appear, which can be seen through the equations of the physics theory of time travel as follows:

$$\frac{GMm}{R} = \frac{mc^2}{2} = mc^2 = hf = h\frac{c}{\lambda} = h\frac{c}{R}$$

In the latter, it can be considered: M = m. In this case, we get the equation for the Planck mass m:

$$m = \sqrt{\frac{hc}{G}} = 2{,}176435 * 10^{-8}\ kg$$

The Planck mass m shows the mass of the smallest black hole in the Universe. A black hole mass smaller than this is no longer possible in the Universe, as the limit is set by the Planck length l. For example, if the Planck mass is represented in the Schwarzschild radius R equation:

$$R = \frac{2GM}{c^2} = \frac{2{,}905236 * 10^{-18}}{299792458^2} = 3{,}23251 * 10^{-35}\ m$$

and if we divide the resulting number by two:

$$\frac{3{,}23251 * 10^{-35}}{2} = 1{,}616255 * 10^{-35}\ m$$

then we get the expression for the Planck length l:

$$l = \sqrt{\frac{Gh}{c^3}} = 1{,}616\ 229(38) * 10^{-35}\ m$$

This shows that the size of a black hole in spacetime cannot be smaller than the Planck length l, which is why the extent of a black hole's mass is limited. However, the mass of a black hole can be indefinitely large.

> The nature of the Planck mass m has long been a great mystery in physics. Many different interpretations have been tried to attribute to it. For example, according to some interpretations, the Planck mass m can also indicate a value of a mass that requires consideration of the laws of quantum physics, such as uncertainty relations. This means that when the mass of a body is equal to the Planck mass m, the effects of quantum mechanics, such as uncertainty relations, begin to manifest. The more mass a body has, the smaller the quantum effects. The Planck mass indicates such a value of a mass (not the size of the body) at which quantum effects are already noticeably large.

From the equation of gravitational potential U and kinetic energy E_k:

$$\frac{GMm}{R} = \frac{mv^2}{2}$$

it was possible to derive the equation for the Schwarzschild radius R:

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

and the equation for the Planck mass m:

$$m = \sqrt{\frac{hc}{G}}$$

However, apart from these two, a third possibility actually manifests itself. For example, since the gravitational potential U can be equal to the quantum energy E:

$$\frac{GMm}{R} = h\frac{c}{R}$$

from which the equation for Planck's mass m is derived, thus it refers to the fact that an extremely small black hole can form at any point in the gravitational field. This means that gravitational fields create black holes with diameters equal to four times the Planck length, and they appear and disappear in a very short period of time. Since they are so small, they have no effect on ordinary matter.

The Schwarzschild radius R is equal to twice the Planck length l:

$$R = 2l$$

thus, the diameter d of a black hole is equal to four times the Planck length l:

$$d = 4l$$

Such a result is not actually logical, since the diameter d of a black hole should still be equal to the Planck length l or only twice, not four times, larger. In the following, we will show that it has its own aspects that can be taken into account. For example, in the Schwarzschild radius R equation:

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

there appears an equation for the Planck length l:

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

or

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

where M is the Planck mass. The latter expression is obtained through a mathematical analysis of the physical theory of time travel as follows:

$$\frac{GMm}{R} = \frac{mc^2}{2} = mc^2 = hf = h\frac{c}{\lambda} = h\frac{c}{R}$$

In this, it can be seen that:

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

or

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

If M is the Planck mass, then we will see that $R = l$:

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

In this case, the Schwarzschild radius R is equal to the Planck length l, so the diameter d of a black hole can be equal to twice the Planck length, not four times anymore. Such a result is already much more logical, since the radius R of the smallest black hole can only be equal to the Planck length l, and can not be smaller or larger than it.

Black holes form in the gravitational field for an extremely short period of time. This is because their mass is equal to the Planck mass m, which is an extremely large mass in the quantum world. For example, from the quantum energy equation:

$$Et = h$$

we can calculate the time period t for the existence of a black hole:

$$t = \frac{h}{E} = \frac{h}{mc^2} = 5{,}39124 * 10^{-44}\ sec$$

Mass m is the Planck mass. The resulting value exactly coincides with the Planck time period t, which is an extremely short time. This time cannot be measured, so such black holes cannot be detected experimentally.

> Furthermore, quantum evaporation calculations also show that such tiny black holes should quantum evaporate almost instantaneously.

Black holes created in gravitational fields are so small and with such a short existence time that they cannot be detected experimentally and therefore have no effect on ordinary matter. But even so, these black holes can affect matter on larger spatial scales, such as at the level of star clusters and galaxies. This means that these tiny black holes can form what we understand as dark matter, which shapes our Universe on a larger scale.

According to the laws of quantum electrodynamics, or quantum field theory, an electromagnetic field can be viewed as a collection of virtual photons or a stream of them:

> The interaction between electrically charged particles consists in one particle absorbing one of the photons emitted by the first. This means that charged particles exchange photons with each other. Each charged particle creates a field around itself, which actually consists of emitting and absorbing photons. However, these photons are not real, but are understood as virtual. These virtual particles cannot be detected while they exist. This is what makes them virtual.

However, a gravitational field is a curvature of spacetime produced by a very large mass of a body. The gravitational field is not an energy field, so the gravitational interaction cannot be mediated by particles.

Quantum field theory describes vacuum polarization, according to which virtual particle-antiparticle pairs are constantly formed in space, which live for a while and then annihilate. For example, in quantum field theory, a virtual electron-positron pair can exist in vacuum at most: $t = 1 * 10^{-22}\ sec.$

> According to quantum field theory, the entire vacuum of the Universe is full of virtual particles, and therefore vacuum actually has an infinitely high energy density. However, as a result of renormalization, the energy density of this vacuum can still be considered practically zero, because such an energy level, which uniformly fills the entire space of our universe, is not actually manifested or measurable in any way. A value of 0 can be read anywhere on an energy scale.

There are similar connections here with the gravitational field, but the gravitational field does not create particles, but instead creates black holes. Black holes appear and disappear in very short periods of time, similar to pairs of particles in vacuum. If pairs of particles created in vacuum are called "virtual", then in principle black holes created in a gravitational field can also be called "virtual", since in both cases they cannot be detected experimentally.

The external centrosymmetric gravitational field of a celestial body is described by the well-known Schwarzschild metric:

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

In this metric equation, the Schwarzschild radius R, or α, appears:

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

Consequently, the gravitational potential U appears in the expression with brackets:

$$\left(1-\frac{\alpha}{r}\right) = \left(1-\frac{2Gm}{c^2 r}\right) = \left(1-\frac{2}{c^2}U\right)$$

In this case, it is clearly seen that the gravitational potential U is limited to a maximum value:

$$U = \frac{Gm}{r} = \frac{c^2}{2}$$

because when it is exceeded, the value under the square root would become negative, which is no longer physical. Negative square roots have only mathematical values. This means that the gravitational potential U and consequently also the gravitational force F are limited to maximum values, values greater than which no longer exist in the universe.

On the Schwarzschild surface at the center of a black hole, spacetime is curved to infinity. For example, gravitational time dilation becomes infinite on the Schwarzschild surface:

$$t` = \frac{t}{\sqrt{1-\frac{2GM}{c^2 r}}} = \frac{t}{\sqrt{1-\frac{R}{r}}} = \frac{t}{\sqrt{1-\frac{R}{R}}} = \infty$$

where

$$\frac{2GM}{c^2 r} = 1$$

From the latter, we see that the black hole's gravitational force cannot be infinitely large on the Schwarzschild surface, as it is related to the maximum possible magnitude of the gravitational potential U in the universe:

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

However, for example, the nuclear force of atoms is related to the Yukawa nuclear potential U:

$$U \propto \frac{1}{r} e^{-r_0 m}$$

according to which the nuclear potential (and consequently also the strong force) becomes infinitely large as the quarks move away from each other to a certain distance in space. This means that removing quarks from each other, i.e. freeing quarks from quark confinement, takes an infinite amount of energy, so an infinitely large force must be applied, which cannot be done anywhere. This points to the interesting fact that in order for the quarks to completely move away from each other, it is necessary to apply a much greater force than the gravitational force of any black hole on the Schwarzschild surface. This means that even the greatest known force in the universe (the gravitational force of a black hole) cannot free quarks from the captivity of the strong force. Of the four types of interaction, the strong interaction is considered the strongest.

A similar principle actually applies to movement speeds. For example, at high speeds, force and acceleration are no longer proportional. If the velocity and force vectors are "in the same direction", then the relativistic equation of Newton's second law is written as:

$$m\gamma a(1+\gamma^2\beta^2)=F$$

From the latter, it can be seen that at high speeds the acceleration a starts to depend not only on the force F but also on the speed v of the body. The consequence of this is that much more force must be applied to give the same acceleration at high speeds than at low speeds. This means that the accelerating force begins to increase without limit as it approaches the speed of light. Consequently, no body (with static mass) can reach or exceed the speed of light. This means that in order to exceed the speed of light, it is necessary to give the body an infinitely large amount of energy, that is, an infinitely large force, which cannot be taken from anywhere, must be applied.

According to popular belief, nothing, not even light, can escape from the center of a black hole. However, a more accurate interpretation would actually be that you can get out of the black hole, but it just takes an infinitely long time, because in case of a black hole, spacetime is curved to infinity, which manifests as infinite time dilation and infinite space contraction. To move the quarks in the nucleus of the atom away from each other, i.e. to free the particles from quark confinement, an infinite amount of energy, which cannot be taken from anywhere, is needed.

> The quarks that exist inside protons and neutrons (or nucleons) cannot be separated from each other. However, it is possible to separate protons and neutrons from each other, which form the nuclei of atoms. A strong force exists between quarks, but a strong nuclear force exists between protons and neutrons, which is interpreted as a remnant of the strong force or a force at the limit of the strong force. It is a bit weaker than the force that manifests itself inside protons and neutrons, or between quarks, but it is still essentially a strong force. The force between quarks is mediated by gluons, but the force between nucleons is mediated by π-mesons.

More specifically, the gravitational potential U:

$$U=\frac{c^2}{2}$$

is the largest possible gravitational potential in the universe, so the Planck force F is:

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

the greatest possible gravitational force in the universe. This means that the strength of the strong interaction can be even greater than that.

The value U of gravitational potential

$$U=\frac{Gm}{R}$$

depends not only on the mass m and the gravitational constant G but also on the value of the radius R. It cannot be smaller than the Planck length l:

$$l=\sqrt{\frac{Gh}{c^3}}=1{,}616\ 229(38)*10^{-35}\ m$$

because there is no perceptible physical reality or the existence of the universe on smaller spatial scales. This means that on scales smaller than the Planck length l, the universe no longer has a physical existence, but can only have a mathematical meaning. Therefore, the gravitational potential U and therefore the gravitational force F cannot be infinitely large. In this sense, the two have certain maximum limits. However, the radius R can be arbitrarily large, so the potential U and therefore the force F can be arbitrarily small. In this case, there are no minimum limits.

Since, according to the physics theory of time travel, the universe is infinitely large, therefore the gravitational potential U and consequently also the gravitational force F can theoretically be indefinitely small. Both depend on the distance of the mass.

If the maximum possible value of the gravitational potential U in the universe is:

$$U = \frac{c^2}{2}$$

then the maximum possible value of the gravitational force F is:

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

The latter is called the Planck force in physics, and no greater force exists in the universe (except for the strong force between quarks in the atomic nucleus).

It should be noted that the gravitational potential U between two masses (M and m) is manifested as follows:

$$U = \frac{GMm}{R}$$

but in case of one mass it has the form:

$$U = \frac{GM}{R}$$

The latter shows the value of the gravitational potential U in the gravitational field of one body.

Gravitational potential U

$$U = \frac{Gm}{R}$$

depends on the mass of a body m. However, the mass of a body cannot be infinitesimally small, since bodies are composed of elementary particles with definite indivisible masses. For example, the value of the rest mass of an electron in atoms is:

$$m = 9{,}109 * 10^{-31}\ kg$$

which could be the smallest value of rest mass in the universe. All masses of elementary particles are known as constants in physics. A particle of infinitesimal mass, i.e. zero mass, is a photon, which is why it moves ceaselessly in vacuum at the speed of light c. Through the mutual equality of the quantum energy E and the gravitational potential U, the value of the Planck mass m_p is obtained:

$$m_p = \sqrt{\frac{hc}{G}} = \sqrt{\frac{hc}{\frac{l_p^2 c^3}{h}}} = \frac{h}{l_p}\frac{1}{c} = 2{,}176435 * 10^{-8}\ kg$$

At this point, it should be said that the masses of bodies in the universe have no upper limit. For example, the mass of a black hole can grow to basically any size.

The gravitational constant G is also related to Planck's constants:

$$G = \frac{l_p^2 c^3}{h} = 6{,}6743 * 10^{-11}\, m^3 kg^{-1} s^{-2}$$

It shows the magnitude of the force F acting between two bodies with masses of 1 kg and a distance of only 1 meter. Therefore, the gravitational interaction is the smallest force in the universe.

On a macroscopic spatial scale (for example, at the level of people, planets, moons, the solar system and galaxies), the gravitational potential U:

$$U = \frac{GM}{R}$$

is precisely mathematically calculable. In this case, classical mechanics applies, in which there are no uncertainty relations known in quantum physics. However, at the quantum level, uncertainties must be taken into account. For example, the position x of a particle cannot be precisely known because of the uncertainty relationship between the particle's position x and momentum p:

$$\Delta x \Delta p = h$$

or

$$\Delta x = \frac{h}{\Delta p}$$

As a result, there must also be uncertainties in the gravitational potential U at the quantum level:

$$\Delta U = \frac{GM}{\Delta R}$$

and thus in case of gravitational force F. This means that, for example, the value of gravitational potential U of a particle or the planet Earth cannot be known precisely at the quantum level (from a certain point after the decimal point). This is due to the uncertainty relations known to us from quantum mechanics. Therefore, at the macroscopic level, the equation for gravitational potential U can be used in its classical form:

$$U = \frac{GM}{R}$$

but at the quantum level it would have the following form:

$$\Delta U = \frac{GM}{\Delta R}$$

This means that any position x or R on the quantum plane is undetermined Δx or ΔR, therefore the gravitational potential U must also be undetermined ΔU. This is also true for the gravitational force F.

1.12 Constants

The Schwarzschild radius R indicates the size of the spherical trapped surface in spacetime, or Schwarzschild surface, on which spacetime has been 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 if the universe no longer has a physical existence on scales smaller than the Planck length l, then absolutely nothing can exist in the "space" inside the Schwarzschild surface S. So the point singularity of a black hole does not actually exist. 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.

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 connected.

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 (2):

$$E = mc^2 = \frac{mc^2}{2} = \frac{E}{2}$$

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: $E = mc^2$ and $\frac{1}{c^4} \to h$.

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 (2):

$$E = mc^2 = \frac{mc^2}{2} = \frac{E}{2}$$

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

$$\frac{1}{c^4} \approx \frac{h}{2\pi}$$

1.13 Black hole and Schwarzschild surface

A general and precise description of the gravitational field is given by Albert Einstein's well-known gravity-field tensor equation:

$$G_{ik}\big(g(x)\big) = -\frac{8\pi G}{c^4} T_{ik}$$

This equation describes how the existence of matter and energy affects the geometry (or metric) of spacetime, as well as the movement of that matter or energy in spacetime. For example, the passage of time slows down in curved spacetime, i.e. when moving towards the center of the gravitational field. Mathematically, this is described by the following gravitational time dilation equation:

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

in which the time differential at infinity is dt. However, using the “binomial expansion”

$$\frac{1}{\sqrt{1-x}} = 1 + \frac{x}{2} + \frac{3}{8}x^2 + \frac{5}{16}x^3 + \cdots$$

it is possible to transform the equation into the following form:

$$T = T_0\left(1 + \frac{gR}{c^2} + \frac{3g^2R^2}{2c^4} + \cdots\right) = T_0(1 + 6{,}95 * 10^{-10} + 7{,}2 * 10^{-19} + \cdots)$$

where g is the gravitational acceleration of the Earth and R is the radius of the Earth. The value

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

is also called the gravitational radius of a celestial body, or today the Schwarzschild radius. Thus, the gravitational time dilation equation can also be written like this:

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

or

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

A gravitational field is a curvature of spacetime caused by very heavy masses. This curvature of spacetime manifests itself, for example, in case of a black hole, in that the further you go towards the center of the black hole's gravitational field, the more time slows down and the distance between two points in space, or "space-length", shortens. This transformation of time and space continues up to a certain distance from the center, and this distance is described by the Schwarzschild radius R:

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

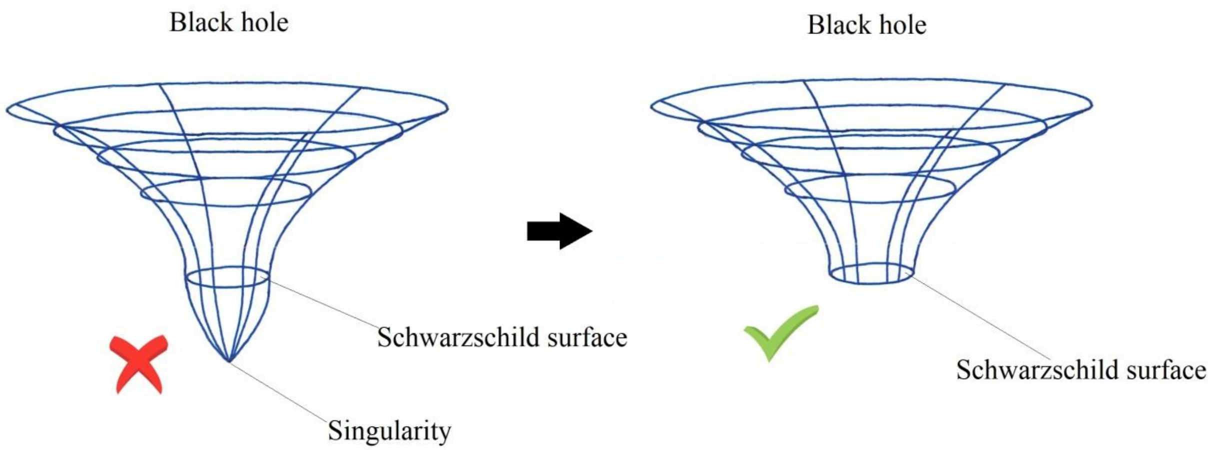
This radius R indicates the distance from the center of the black hole's gravitational field, from where time t and space l have transformed to infinity, i.e. from where the infinite curvature of spacetime manifests, i.e. the "absolute" cessation of the existence of spacetime:

$$t = \frac{t_0}{\sqrt{1 - \frac{2GM}{c^2 r}}} = \frac{t_0}{\sqrt{1 - \frac{R}{r}}} = \frac{t_0}{\sqrt{1 - \frac{R}{R}}} = \infty$$

and

$$l = l_0 \sqrt{1 - \frac{2GM}{c^2 r}} = l_0 \sqrt{1 - \frac{R}{r}} = l_0 \sqrt{1 - \frac{R}{R}} = 0$$

Therefore, 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. Figure:



Due to the analysis presented above, 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".

From the well-known Schwarzschild radius equation:

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

it can be directly seen that the Earth's mass M creates a hole in spacetime with radius R. From this very simple relationship alone, it can be concluded with certainty that the presence of Earth's mass M alone creates a hole in spacetime with radius R, not the collapse of the Earth to the size of a sphere with a radius R. Earth collapsing to a radius R would simply allow this hole in spacetime to be visually seen, rather than being the cause of it. This means that the cause of the hole in spacetime is primarily mass, not the collapse of mass. It follows that there must exist a hole in spacetime with radius R at the center of the Earth, which can also be interpreted as a black hole.

According to Schwarzschild's external metric, there should be a hole in spacetime at the center of any (celestial body) gravitational field (not only at the center of a black hole). This means that according to the external Schwarzschild metric, there is a Schwarzschild surface at the center of the planet and/or star (gravitational field), which can be interpreted as a black hole. For example, there should also be a hole in spacetime at the center of the planet Earth according to the Schwarzschild metric, which can also be interpreted as a "black hole". Due to the rotation of the planet Earth on its imaginary axis and its orbit around the Sun, the Schwarzschild surface at the center of the Earth cannot be perfectly spherical, i.e. it would also have to rotate. Its existence in the center of the planet Earth would be proven by the fact that clocks run slower the closer they are to the center of the Earth's gravitational field, i.e. gravitational time dilation applies

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

and with it also the gravitational contraction of the length (that is, the distance between two points in space)

$$l = l_0 \sqrt{1 - \frac{2GM}{c^2 r}} = l_0 \sqrt{1 - \frac{R}{r}}$$

in which there is a Schwarzschild radius R. Clocks stop, i.e. time "stops" at a certain distance from the center, and this distance from the center is described by the well-known Schwarzschild radius R. In a hole in spacetime (that is, in the center of a black hole), spacetime is curved to infinity, i.e. time has slowed down to infinity, and between two points in space distance has reduced to infinity. A "black hole" at the center of the Earth would have a radius of only 8.86 mm.

> At this point, the question may arise that how is it possible that a black hole exists at the center of the Earth. Why doesn't a black hole swallow the Earth? There is actually no objective answer to such an emerging question (for example, the causes of the Earth's magnetic field are still not exactly known). However, some scientific hypotheses trying to explain it are based on the fact that a black hole is extremely small (with a radius of 8.86 mm) compared to the size of the Earth itself, the gravitational force is much greater in the interior of the Earth, and the interior of the Earth also rotates much faster than we can imagine. All these aspects make up the complete geophysics of the Earth as a planet, in which the Earth and the black hole inside the Earth remain in perfect balance. In this case, the black hole does not absorb the Earth. It is exactly the same with stars. For example, if there was a black hole instead of the Sun, but with the mass of the Sun, then such a black hole would not absorb the planets that exist in the Solar System, including the Earth and the Moon.
>
>> For example, the density of matter in the Earth's core is very high. The gravitational force on the outer surface of the Earth's core is about 3 times greater than it is on the Earth's surface. Earth's solid inner core, almost the size of the Moon, rotates much faster than the planet itself. It rotates eastward, but Earth's molten metal outer core rotates westward and much more slowly.
>>
>> The core of the earth has a very high temperature. This is due to the high pressure, which in turn is caused by a much greater gravitational force than there is on earth.

According to the external Schwarzschild metric, the centers of light-emitting stars should also have Schwarzschild surfaces, or holes in spacetime (i.e. "black holes"), which should also rotate. This circumstance leads to the idea that black holes are not actually created by the collapse of dying stars, but are actually present in the centers of stars during their lifetime.

Black holes are formed from stars with 2-3 times the mass of the Sun, when they start to collapse under their own weight at the end of their life, because the gravitational force directed into the interior of a star exceeds the pressure caused by thermonuclear reactions, which have shrunk to almost nothing. Since the pressure balance between the gravitational force directed inside the star and the thermonuclear reactions directed outside the star is broken at the end of the star's life (in favor of the gravitational force) and the outer layers of the star are thrown away as a "supernova explosion", a black hole is formed as a result of the gravitational collapse of the star's mass.

The death of a star begins at the stage when most of the hydrogen has been used up, i.e. hydrogen has turned into helium. As a result, the energy production of the star decreases and the balance between the pressure of the emitted radiation and the high gravitational force is disturbed. This causes the star's core to contract, during which the temperature and pressure increase and thermonuclear reactions intensify. However, at the same time, the outer shell of the star expands and cools. As a result, the star expands several times and the surface temperature of the star decreases. This is how the star turns into a red giant in the dying stage. However, the star's core contracts and heats up. Helium nuclei begin to fuse only when the temperature has reached 10^8 K. At some stage in a star's life, nuclear fusion reactions stop, i.e. there is no more energy for future nuclear reactions. In this case, the star contracts under the influence of gravitational forces. If the mass of the star is greater than three of the masses of the Sun, then due to its great gravitational force, the density of the star exceeds the density of an ordinary atomic nucleus. This is allegedly how a black hole is formed - from the collapsing cores of stars.

However, black holes do not actually form as a result of supernova explosions of dying stars, but are already present in the centers of stars during their lifetime. When the star's core contracts due to the great gravitational force, the dimensions of the star's core change to the size of a black hole already existing in the core, or a hole in spacetime. According to this understanding, black holes are not actually created by the collapse of stars, but simply become visible due to the contraction of stellar cores. They are already present in the centers of stars during their lifetime.

The "black hole" at the center of a star does not absorb the star during the lifetime of the star, because the black hole is extremely small compared to the star, the gravitational field of the black hole "matches" the gravitational field of the star, and the gravitational force directed to the interior of the star and the pressure due to thermonuclear reactions directed outside the star are in balance during the lifetime of the star. In principle, this also applies to planets and even moons.

Since all celestial bodies mostly rotate around their imaginary axis (e.g. planets, stars and moons), it can therefore be concluded that spherical Schwarzschild surfaces do not exist in the centers of celestial bodies, but rather have an elliptical shape. Such a conclusion follows directly from the rotations of celestial bodies. For example, in case of a rotating black hole, it is believed that an elliptical Schwarzschild surface exists at its center, rather than a spherical Schwarzschild surface. This line of thinking also extends to Schwarzschild surfaces at the center of other celestial bodies.

One reason for this is that, for example, a gyroscope precesses a rotating gravitational field source in motion, in which case the axis of the gyroscope starts to change its direction as it rotates around the source. In physics, this is called the inertial background system or ITS entrainment effect, since the ITS of the body starts to rotate as it approaches the source. Such a phenomenon occurs, for example, with the movement of a gyroscope together with a polar satellite around the

Earth. The axis of rotation of the satellite changes by 0.00184 degrees of arc per year and the entrainment of spacetime near the Earth, which changes the plane of rotation of the satellite relative to the plane of rotation of the Earth by 0.0000114 degrees per year.

Elliptical shapes are mostly accompanied by rotation, not spherical shapes. For example, the Earth is also actually elliptical in shape, not perfectly spherical. The same principle applies to the Schwarzschild surface at the center of the Earth.

1.13.1 Endnote: black holes are not actually created by dying stars, they already exist during the lifetime of stars

Black holes are formed from stars with 2-3 times the mass of the Sun, when they start to collapse under their own weight at the end of their life, because the gravitational force directed into the interior of the star exceeds the pressure caused by thermonuclear reactions, which have shrunk to almost nothing. Since the pressure balance between the gravitational force directed inside the star and the thermonuclear reactions directed outside the star is broken at the end of the star's life (in favour of gravitational force) and the outer layers of the star are thrown away as a "supernova explosion", a black hole is formed as a result of the gravitational collapse of the star's mass.

The dying of the star begins at the stage when most of the hydrogen has been used up, i.e. hydrogen has turned into helium. As a result, the energy production of the star decreases and the balance between the pressure of the emitted radiation and the strong gravitational force is disturbed. This causes the star's core to contract, during which the temperature and pressure increase and thermonuclear reactions intensify. However, at the same time, the outer shell of the star expands and cools. As a result, the star expands several times and the surface temperature of the star decreases. This is how the star turns into a red giant in the dying stage. However, the star's core contracts and heats up. Helium nuclei begin to fuse only when the temperature reaches 10^8 K. At some stage in a star's life, nuclear fusion reactions stop, i.e. there is no more energy for future nuclear reactions. In this case, the star contracts under the influence of gravitational forces. If the mass of the star is greater than three of the masses of the Sun, then due to its great gravitational force, the density of the star exceeds the density of an ordinary atomic nucleus. This is allegedly how a black hole is formed - from collapsing stellar nuclei.

However, black holes do not actually form as a result of supernova explosions of dying stars, but are present in the centres of stars during their lifetime. When the star's core contracts due to the great gravitational force, the dimensions of the star's core change to the size of the black hole already in the core, or a hole in spacetime. According to this understanding, black holes are not actually created by the collapse of stars, but simply become visible due to the contraction of stellar cores. They are already present in the centres of stars during their lifetime.

The "black hole" in the centre of the star does not absorb the star during the lifetime of the star, because the black hole is extremely small compared to the star, the gravitational field of the black hole "matches" the gravitational field of the star, and the gravitational force directed inside the star and the pressure due to thermonuclear reactions directed outside the star are in balance during the life of the star. In principle, this also applies to planets and even moons.

According to Schwarzschild's external metric, there should be a hole in spacetime at the centre of any (celestial body’s) gravitational field (not only at the centre of a black hole). This means that according to the external Schwarzschild metric, there is a Schwarzschild surface at the centre of the planet and/or star (gravitational field), which can be interpreted as a black hole. For example, there should also be a hole in spacetime at the centre of the planet Earth according to the Schwarzschild metric, which can also be interpreted as a "black hole". Due to the rotation of the planet Earth on its imaginary axis and its orbit around the Sun, the Schwarzschild surface at the centre of the Earth cannot be perfectly spherical, i.e. it would also have to rotate. Its existence at the centre of the planet Earth would be proven by the fact that the clocks run the slower the closer they are to the centre of the Earth's gravitational field, i.e. the gravitational time dilation applies and with it also the gravitational length contraction (i.e. the distance between two points in space), in which the Schwarzschild radius R manifests. The clocks stop or time "stops" at a certain distance from the centre and this distance from the centre is described by the well-known Schwarzschild radius R. In a hole in spacetime (or at the centre of a black hole), spacetime is curved to infinity, that is, time has slowed down to infinity and the distance between two points in space has decreased to infinity. A "black hole" at the centre of the Earth would have a radius of only 8.86 mm.

The density of matter in the Earth's core is very high. The gravitational force on the outer surface of the Earth's core is about 3 times greater than it is on the Earth's surface. Earth's solid inner core, almost the size of the Moon, rotates much faster than the planet itself. It rotates eastward, but Earth's molten metal outer core rotates westward and much more slowly.

The core of the Earth has a very high temperature. This is due to the high pressure, which in turn is caused by a much greater gravitational force than there is on earth.

According to the external Schwarzschild metric, the centres of light-emitting stars should also have Schwarzschild surfaces, or holes in spacetime (i.e. "black holes"), which should also rotate. This circumstance leads to the idea that black holes are not actually created by the collapse of dying stars, but are actually present in the centres of stars during their lifetime.

The gravitational field is, in physical terms, the curvature of spacetime. Basically, it can be understood that the curvature of spacetime is caused by a hole in spacetime, but the hole in spacetime is in turn caused by the body's mass (i.e. mass density). In this case, the mass of the body is not "inside" the hole in spacetime, but "outside" of it. The curvatures of spacetime are created by holes in spacetime located at the centres of gravitational field. For example, a hole in spacetime is described by the ratio of the Schwarzschild radius to the actual radius of an object, where time and space transform when moving toward the hole in spacetime. The Schwarzschild radius R_s determines the size of the hole in spacetime, and the radius R of a celestial object determines the size of the object itself. A hole in spacetime is mostly located at the centre of the gravitational field and thus at the centre of celestial objects. The Schwarzschild radius, or event horizon R_s, calculated by Karl Schwarzschild, is actually used in all the equations of general relativity.

The light emitted by the atoms is shifted towards the red part of the spectrum in the gravitational field. The closer the emitting atom is to the centre of the gravitational field, the more the light's oscillation frequency decreases. American physicists P. V. Pound and G. A. Rebka used the Mössbauer effect to experimentally detect such a gravitational shift of the photon frequency. General relativity tells us that as the gravitational potential changes, the frequency of the photon must also change, and the heavy mass of a photon is equal to its inertial mass. A homogeneous gravitational field is characterized by the gravitational acceleration g. If a photon in such a field passes a distance l in the opposite direction to the direction of gravity F = mg, then the energy of the photon decreases. The change in gravitational potential is proportional to the relative change in the photon's angular frequency.

Gravitational redshift means that all spectral lines of stars must be slightly shifted towards the red end of the spectrum, as the light reaching Earth from the Sun or stars must overcome the strong pulling field of these light sources. Near the Earth, light is affected by a very weak accelerating field. The phenomenon of gravitational redshift was discovered by Pound and Rebka in an experiment performed under terrestrial conditions. They placed a y-radiation source (57Fe) and an absorber 21 meters apart in one tall tower. When traveling such a distance, the relative change in the angular frequency of the y-quantum is $\approx 2 * 10^{-15}$. Such a change causes a shift of the absorption and emission lines, which is manifested in a small decrease in the resonant absorption. The shift was only 10^{-2} linewidth. The result was 0,99$\pm$0,05 of what was predicted by theory. This was the first time that the gravitational redshift of a photon could be convincingly demonstrated in a ground-based laboratory.

1.14 The gravitational field inside the celestial body

The well-known Schwarzschild metric

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

or

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

describes only the outer space-time curvature of a celestial body, i.e. the "*pure*" gravitational field. Such a metric does not describe the gravitational field inside the celestial body. However, to find such a description, we can perform the following mathematical transformations in the Schwarzschild metric:

$$\left(1 - \frac{r_s}{r}\right) c^2 dt^2 = \frac{4}{4}\left(1 - \frac{r_s}{r}\right) c^2 dt^2 = \frac{1}{4}\left(2\sqrt{1 - \frac{r_s}{r}}\right)^2 c^2 dt^2 =$$

$$= \frac{1}{4}\left(2\sqrt{1 - \frac{r_s}{r}}\right)^2 c^2 dt^2 = \frac{1}{4}\left(\sqrt{1 - \frac{r_s}{r}} + \sqrt{1 - \frac{r_s}{r}}\right)^2 c^2 dt^2 =$$

$$= \frac{1}{4}\left(\sqrt{1 - \frac{r_s}{r}} + \sqrt{1 - \frac{r_s}{r}}\right)^2 c^2 dt^2 = \frac{1}{4}\left(\sqrt{1 - \frac{r_s}{r}} + \sqrt{1 - \frac{r_s}{r}} + \sqrt{1 - \frac{r_s}{r}} - \sqrt{1 - \frac{r_s}{r}}\right)^2 c^2 dt^2 =$$

$$= \frac{1}{4}\left(\sqrt{1 - \frac{r_s}{r}} + \sqrt{1 - \frac{r_s}{r}} + \sqrt{1 - \frac{r_s}{r}} - \sqrt{1 - \frac{r_s}{r}}\right)^2 c^2 dt^2 = \frac{1}{4}\left(3\sqrt{1 - \frac{r_s}{r}} - \sqrt{1 - \frac{r_s}{r}}\right)^2 c^2 dt^2$$

The resulting mathematical transformation gives us the Schwarzschild metric in the following form:

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

or

$$g = \frac{1}{4}\left(3\sqrt{1 - \frac{r_s}{r}} - \sqrt{1 - \frac{r_s}{r}}\right)^2 c^2 dt^2 - \left(1 - \frac{r_s}{r}\right)^{-1} dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

where the Schwarzschild radius is:

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

As mass density is expressed as:

$$\rho = \frac{M}{V(R)}$$

and the equation for the volume of a sphere can be written:

$$V(R) = \frac{4}{3}\pi R^3$$

then the "mass function" can be expressed as the following relation:

$$M(r) = V(r)\rho = \frac{r^3}{R^3}M$$

Consequently, we can write:

$$\frac{2GM(r)}{rc^2} = \frac{2GMr^2}{R^3c^2} = \frac{r_s r^2}{R^3} = \frac{r_s r^2}{r_g^3}$$

or

$$\frac{r_s}{r} = \frac{r_s}{r}\frac{r^2}{r^2} = \frac{r_s r^2}{r^3} = \frac{r_s r^2}{r_g^3} = \frac{r^2}{R^2}$$

Therefore, we get the following relation as the final form of the Schwarzschild metric:

$$g = \frac{1}{4}\left(3\sqrt{1-\frac{r_s}{r}} - \sqrt{1-\frac{r_s}{r}}\right)^2 c^2dt^2 - \left(1-\frac{r_s}{r}\right)^{-1} dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

or

$$g = \frac{1}{4}\left(3\sqrt{1-\frac{r^2}{R^2}} - \sqrt{1-\frac{r^2}{R^2}}\right)^2 c^2dt^2 - \left(1-\frac{r^2}{R^2}\right)^{-1} dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

or

$$g = \frac{1}{4}\left(3\sqrt{1-\frac{r_g^2}{R^2}} - \sqrt{1-\frac{r^2}{R^2}}\right)^2 c^2dt^2 - \left(1-\frac{r^2}{R^2}\right)^{-1} dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

which describes the curvature of space-time inside a celestial body and thus the gravitational field. However, in the preceding equations, it must be taken into account that:

$$r^2 = r^2$$

$$r_g^2 \neq r^2$$

$$R^2 = \frac{r_g^3}{r_s}$$

and the latter metric equation g can also be expressed mathematically as follows:

$$g = c^2d\tau^2 = \left(\frac{3cos\eta_g - cos\eta}{2}\right)^2 c^2dt^2 - \frac{dr^2}{cos^2\eta} - r^2(d\theta^2 + sin^2\theta d\varphi^2)$$

where

$$\eta = sin^{-1}\frac{r}{R}$$

$$\eta_g = sin^{-1}\frac{r_g}{R} = sin^{-1}\sqrt{\frac{r_s}{r_g}}$$

According to the Kerr metric, a black hole rotates. This means that the well-known Schwarzschild metric:

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

describes the space-time of a black hole in which the black hole does not rotate. To describe the spacetime of a rotating black hole, or Kerr black hole, we first derive Kerr's metric equation from the conventional spacetime interval metric equation:

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

For this we need to use spherical coordinates:

$$x = \sqrt{r^2+a^2}sin\theta cos\varphi$$

$$y = \sqrt{r^2+a^2}sin\theta sin\varphi$$

$$z = rcos\theta$$

the differentials of which are equal to:

$$dx = \frac{r}{\sqrt{r^2+a^2}}sin\theta cos\varphi dr + \sqrt{r^2+a^2}cos\theta cos\varphi d\theta - \sqrt{r^2+a^2}sin\theta sin\varphi d\varphi$$

$$dy = \frac{r}{\sqrt{r^2+a^2}}sin\theta sin\varphi dr + \sqrt{r^2+a^2}cos\theta sin\varphi d\theta + \sqrt{r^2+a^2}sin\theta cos\varphi d\varphi$$

$$dz = cos\theta dr - rsin\theta d\theta$$

Such expressions give us the shape of the spatial part of the interval metric equation:

$$dx^2+dy^2 + dz^2 = \left(\frac{r^2}{r^2+a^2}sin^2\theta+cos^2\theta\right)dr^2 +$$

$$+\left((r^2+a^2)cos^2\theta + r^2sin^2\theta\right)d\theta^2 + (r^2+a^2)sin^2\theta d\varphi^2 =$$

$$= \frac{r^2+a^2cos^2\theta}{r^2+a^2}dr^2 + (r^2+a^2cos^2\theta)d\theta^2 + (r^2+a^2)sin^2\theta d\varphi^2$$

or

$$dx^2+dy^2 + dz^2 = \frac{r^2+a^2cos^2\theta}{r^2+a^2}dr^2 + (r^2+a^2cos^2\theta)d\theta^2 + (r^2+a^2)sin^2\theta d\varphi^2$$

If we consequently use in the “normal” Schwarzschild metric:

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

such a geometric relationship:

$$r^2=\Lambda=r^2+a^2cos^2\theta$$

then we can get as a result:

$$\left(1-\frac{r_s}{r}\right)^{-1}dr^2=\frac{r^2+a^2cos^2\theta}{r^2-r_sr+a^2}dr^2$$

where the following es expressed in return

$$\Delta=r^2-r_sr+a^2=r^2-2Mr+a^2$$

This is very important to understand what follows, as we can derive the 'metric determinant' from it:

$$(r^2-2Mr+a^2)(-sin^2\theta)=\Delta(-sin^2\theta)=-\Delta sin^2\theta=-(r^2+a^2)sin^2\theta+2Mrsin^2\theta=$$

$$=-(r^2+a^2)sin^2\theta+\frac{2Mr}{\Lambda}sin^2\theta[-a^2sin^2\theta+r^2+a^2]=$$

$$=-\left[r^2+a^2+\frac{2Mra^2}{\Lambda}sin^2\theta\right]sin^2\theta+(r^2+a^2)\frac{2Mr}{\Lambda}sin^2\theta=$$

$$=-\left(1-\frac{2Mr}{\Lambda}\right)\left[r^2+a^2+\frac{2Mra^2}{\Lambda}sin^2\theta\right]sin^2\theta-\frac{4M^2r^2a^2}{\Lambda^2}sin^4\theta=g_{tt}g_{\varphi\varphi}-g^2{}_{t\varphi}=\tilde{g}$$

The resulting determinant describes the matrix:

$$\tilde{g}_{ab}=\begin{pmatrix}g_{tt} & g_{t\varphi}\\ g_{t\varphi} & g_{\varphi\varphi}\end{pmatrix}$$

which in turn is related to the metric tensor:

$$g_{\mu\nu}=\begin{pmatrix}g_{tt} & 0 & 0 & g_{t\varphi}\\ 0 & \frac{\Lambda}{\Delta} & 0 & 0\\ 0 & 0 & \Lambda & 0\\ g_{t\varphi} & 0 & 0 & g_{\varphi\varphi}\end{pmatrix}$$

The members in it are expressed as follows:

$$g_{tt}=-\left(1-\frac{2Mr}{\Lambda}\right)$$

$$g_{t\varphi}=-\frac{2Mr}{\Lambda}asin^2\theta$$

$$g_{\varphi\varphi}=\left[r^2+a^2+\frac{2Mra^2}{\Lambda}sin^2\theta\right]sin^2\theta$$

$$g_{\varphi\varphi} = \left[r^2 + a^2 + \frac{2Mra^2}{\Lambda} sin^2\theta\right] sin^2\theta = (r^2 + a^2) sin^2\theta + \frac{2Mra^2 sin^4\theta}{\Lambda} =$$

$$= \frac{sin^2\theta}{\Lambda}\left[(r^2 + a^2 cos^2\theta)(r^2 + a^2) + 2Mra^2 sin^2\theta\right] =$$

$$= \frac{sin^2\theta}{\Lambda}\left[(r^2 + a^2)^2 - (r^2 + a^2)a^2 sin^2\theta + 2Mra^2 sin^2\theta\right] =$$

$$= \frac{sin^2\theta}{\Lambda}\left[(r^2 + a^2)^2 - a^2 sin^2\theta\Delta\right]$$

However, the metric tensor can be "written out" as follows:

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

or

$$ds^2 = -\left(1 - \frac{2Mr}{\Lambda}\right)c^2 dt^2 - \frac{2aMr}{\Lambda} sin^2\theta c dt d\varphi + \frac{(r^2 + a^2)^2 - a^2\Delta sin^2\theta}{\Lambda} sin^2\theta d\varphi^2 +$$

$$+ \frac{\Lambda}{\Delta} dr^2 + \Lambda d\theta^2$$

where

$$\Lambda = r^2 + a^2 cos^2\theta$$

$$\Delta = r^2 - r_s r + a^2 = r^2 - 2Mr + a^2$$

$$r = a = \frac{J}{Mc}$$

The resulting metric already describes a rotating black hole, in which case the Schwarzschild surface can no longer be completely spherical.

> The Schwarzschild surface cannot be perfectly spherical for a rotating black hole, but according to some academic literature it is perfectly spherical. This means that there are conflicting educational literary sources in this field.

However, here we have to explain a little more how we got the Kerr metric from the metric tensor. First, we have a very interesting mathematical relationship here:

$$-\Delta sin^2\theta = -\left(1 - \frac{2Mr}{\Lambda}\right)\left[r^2 + a^2 + \frac{2Mra^2}{\Lambda} sin^2\theta\right] sin^2\theta - \frac{4M^2 r^2 a^2}{\Lambda^2} sin^4\theta = g_{tt} g_{\varphi\varphi} - g^2{}_{t\varphi}$$

where

$$g_{tt} g_{\varphi\varphi} - g^2{}_{t\varphi} = \tilde{g}$$

and

$$\tilde{g}_{ab} = \begin{pmatrix} g_{tt} & g_{t\varphi} \\ g_{t\varphi} & g_{\varphi\varphi} \end{pmatrix}$$

A little later we will prove the derivation of quantity Δ

$$\Delta = r^2 - r_s r + a^2 = r^2 - 2Mr + a^2$$

that the following mathematical transformation is possible:

$$\frac{r^2 + a^2 cos^2\theta}{r^2 + a^2} dr^2 \;\; \rightarrow \;\; \frac{r^2 + a^2 cos^2\theta}{r^2 - r_s r + a^2} dr^2$$

which basically gives the value Δ. However, in the long equation derived above:

$$-\Delta sin^2\theta = -\left(1 - \frac{2Mr}{\Lambda}\right)\left[r^2 + a^2 + \frac{2Mra^2}{\Lambda} sin^2\theta\right] sin^2\theta - \frac{4M^2 r^2 a^2}{\Lambda^2} sin^4\theta = g_{tt} g_{\varphi\varphi} - g^2{}_{t\varphi}$$

the following interesting relation stands out:

$$\left[r^2 + a^2 + \frac{2Mra^2}{\Lambda} sin^2\theta\right] sin^2\theta$$

which in turn suggests the possibility of the following mathematical transformation:

$$(r^2 + a^2) sin^2\theta \;\; \rightarrow \;\; \left[r^2 + a^2 + \frac{2Mra^2}{\Lambda} sin^2\theta\right] sin^2\theta$$

The spatial coordinate differentials were equal to:

$$dx^2 + dy^2 + dz^2 = \frac{r^2 + a^2 cos^2\theta}{r^2 + a^2} dr^2 + (r^2 + a^2 cos^2\theta) d\theta^2 + (r^2 + a^2) sin^2\theta d\varphi^2$$

which can now also be expressed mathematically as follows:

$$dx^2 + dy^2 + dz^2 = \frac{r^2 + a^2 cos^2\theta}{r^2 - r_s r + a^2} dr^2 + (r^2 + a^2 cos^2\theta) d\theta^2 +$$

$$+ \left[r^2 + a^2 + \frac{2Mra^2}{\Lambda} sin^2\theta\right] sin^2\theta d\varphi^2$$

or

$$dx^2 + dy^2 + dz^2 = \frac{\Lambda}{\Delta} dr^2 + \Lambda d\theta^2 + \left[r^2 + a^2 + \frac{2Mra^2}{\Lambda} sin^2\theta\right] sin^2\theta d\varphi^2$$

Consequently, in the equation:

$$\tilde{g}_{ab} = \begin{pmatrix} g_{tt} & g_{t\varphi} \\ g_{t\varphi} & g_{\varphi\varphi} \end{pmatrix}$$

we need to add terms such as $\frac{\Lambda}{\Delta}$ and Λ to the term $g_{\varphi\varphi}$. The result is a metric tensor:

$$g_{\mu\nu} = \begin{pmatrix} g_{tt} & 0 & 0 & g_{t\varphi} \\ 0 & \frac{\Lambda}{\Delta} & 0 & 0 \\ 0 & 0 & \Lambda & 0 \\ g_{t\varphi} & 0 & 0 & g_{\varphi\varphi} \end{pmatrix}$$

It is appropriate to mention here that the Schwarzschild metric:

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

was also described by the metric tensor:

$$g_{\mu\nu} = \begin{bmatrix} \left(1 - \frac{2GM}{rc^2}\right) & 0 & 0 & 0 \\ 0 & -\left(1 - \frac{2GM}{rc^2}\right)^{-1} & 0 & 0 \\ 0 & 0 & -r^2 & 0 \\ 0 & 0 & 0 & -r^2 sin^2\theta \end{bmatrix}$$

Consequently, the following metric tensor:

$$g_{\mu\nu} = \begin{pmatrix} g_{tt} & 0 & 0 & g_{t\varphi} \\ 0 & \frac{\Lambda}{\Delta} & 0 & 0 \\ 0 & 0 & \Lambda & 0 \\ g_{t\varphi} & 0 & 0 & g_{\varphi\varphi} \end{pmatrix}$$

can be described by the following metric equation:

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

$$-\frac{2aMr}{\Lambda} sin^2\theta cdtd\varphi$$

or

$$ds^2 = -\left(1 - \frac{2Mr}{\Lambda}\right) c^2 dt^2 - \frac{2aMr}{\Lambda} sin^2\theta cdtd\varphi + \frac{(r^2 + a^2)^2 - a^2 \Delta sin^2\theta}{\Lambda} sin^2\theta d\varphi^2 +$$

$$+\frac{\Lambda}{\Delta} dr^2 + \Lambda d\theta^2$$

There is a "*quantity*" in the Kerr metric equation without which the Kerr metric could not be derived:

$$\Delta = r^2 - r_s r + a^2 = r^2 - 2Mr + a^2$$

This very important relationship can be “*derived*” as follows:

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

Since in spatial coordinate differentials

$$dx^2+dy^2+dz^2=\frac{r^2+a^2cos^2\theta}{r^2+a^2}dr^2+(r^2+a^2cos^2\theta)d\theta^2+(r^2+a^2)sin^2\theta d\varphi^2$$

we can understand the following an act of 'mathematical transformation':

$$\frac{r^2}{r^2}dr^2\rightarrow\frac{r^2+a^2cos^2\theta}{r^2+a^2}dr^2$$

therefore, we can do exactly the same with the following relation:

$$\frac{r^2}{r^2-r_sr}dr^2\rightarrow\frac{r^2+a^2cos^2\theta}{r^2-r_sr+a^2}dr^2$$

Consequently, we can write the equations:

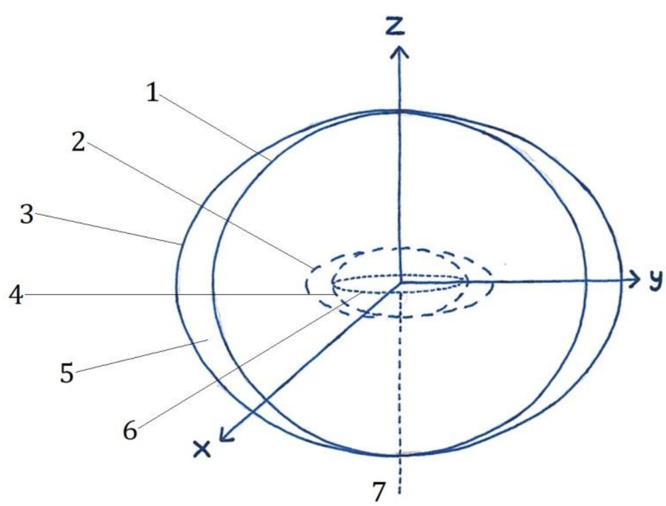
$$\left(1-\frac{r_s}{r}\right)^{-1}dr^2=\frac{r^2+a^2cos^2\theta}{r^2-r_sr+a^2}dr^2=\frac{r^2}{r^2-r_sr}dr^2=\frac{r^2}{r^2\left(1-\frac{r_sr}{r^2}\right)}dr^2=\frac{1}{1-\frac{r_s}{r}}dr^2$$

but only in case $a=0$. In the latter, we can see that the "value" we are looking for is present in it:

$$\Delta=r^2-r_sr+a^2=r^2-2Mr+a^2$$

Kerr's black hole metric is based on vacuum solutions of Einstein's field equations, in which the mass of the collapsing star is not taken into account.

Black hole regions and boundary surfaces according to the Kerr metric:



1. Outer event horizon: $r_+=m+\sqrt{m^2-a^2}$
2. Inner event horizon: $r_-=m-\sqrt{m^2-a^2}$
3. Outer ergosurface: $r_E^+=m+\sqrt{m^2-a^2cos^2\theta}$

4. Inner ergosurface: $r_E^- = m - \sqrt{m^2 - a^2 cos^2\theta}$
5. Ergoregion
6. Ring singularity: $x^2 + y^2 = a^2,\ z = 0$
7. Symmetry axis: $\theta = 0, \pi$

A rotating black hole is surrounded by two horizons: the stationarity track and the event horizon. The stationarity track is compressed above the poles of the black hole, but at the equator it extends slightly beyond the event horizon. The event horizon of the black hole (or the surface of the black hole) itself is no longer completely spherical and it "rotates", and at its center is a circular singularity (which does not actually exist). Between the stationarity track and the event horizon lies the ergosphere, where absolutely all bodies rotate around the black hole and their rotation directions coincide with the direction of rotation of the black hole. No body stays still in the ergosphere, but it is possible to get out. There is no escape from the event horizon of a black hole.

Since in case of the Schwarzschild metric, or non-rotating black hole, we concluded that the black hole singularity does not exist, this understanding actually also applies to the case of rotating black holes, or the Kerr metric. In case of black holes, we only have to consider trapped surfaces in spacetime, or event horizons, with time and space curved to infinity. Absolutely everything that remains "inside" of it is no longer physically real.

Due to the rotation of the black hole, the poles of the spin axis emit matter, which eventually leads to the extinction of the black hole. Any matter that falls into a black hole creates a flux of electromagnetic radiation into the space surrounding the black hole. From the poles of the black hole's rotation axis, large streams of radiation emanate into the surrounding space in opposite directions. According to them, it is possible to calculate the energy of the black hole.

For example, a stellar-mass black hole called 4U 1630-472 rotates at about 92-95% of the theoretical maximum rotation speed. Matter falling into a black hole is extremely hot and emits bright X-rays as the matter falls into the black hole at extremely high acceleration. A rotating black hole transforms the time and space around it differently than a non-rotating black hole. The emitted radiation of matter falling into a black hole leaves its traces, which astronomers are also able to record.

The Schwarzschild metric, known from general relativity, describes the gravitational field that occurs outside celestial bodies. Therefore, it is also simply called the external metric. Intrinsic metrics describe the gravitational field that exists inside celestial bodies. The field of external metric in theoretical physics is very wide: it describes the gravitational field between celestial bodies, the movements of celestial bodies in space, the bending of light rays near stars, and can also predict future events in astronomy. In Albert Einstein's gravitational field equation, it is the expression of the external metric, not the expression of the internal metric, that appears. However, the field of use of the internal metric is much narrower: it describes the internal gravitational field of celestial bodies, especially the internal gravitational processes of black holes, and, for example, also contributes to the description of Earth's geophysics. Newtonian mechanics may also be used instead of the intrinsic metric, and the intrinsic metric is mathematically derived from the expression for the extrinsic metric. Therefore, it can be said that the use of the external metric is obviously more dominant in theoretical physics, which is why the course of the internal metric is sometimes neglected in general relativity teachings.

As noted above, internal metrics describe the gravitational field that exists inside a celestial body. However, it can also be noted here that the importance of internal metrics comes into play when we describe the gravitational processes inside black holes. Intrinsic metrics are important precisely because they describe the gravitational fields of black holes very well. For example, in the construction of black holes, concepts such as inner and outer Schwarzschild surface, inner and outer ergosphere, point and circular singularity, rotating and non-rotating black hole gravitational field, and stationary path are used. All these aspects are described by mathematical expressions derived from the internal metric.

Above we showed that there must exist a hole in spacetime at the center of any celestial body, which can be interpreted as a black hole described in astrophysics. However, it must be noted that this is primarily shown by an external metric equation, such as the Schwarzschild metric, in which Schwarzschild radii occur. The internal metric equations that describe the gravitational field inside a celestial body do not show this, although they also include Schwarzschild radii. Since the internal metrics are mathematically derived from the external metric, the external metric is nevertheless more general and fundamental, so the resulting interpretations and conclusions can still be taken seriously.

According to Isaac Newton's law of gravitation

$$F = G\frac{M}{r^2}$$

there exists a "point" at the center of the celestial body "at which" the gravitational force F becomes infinitely large:

$$F = G\frac{M}{r^2} = \frac{GM}{0} = \infty$$

Such an interpretation or conclusion is no longer correct today. Even on the surface of a black hole, the gravitational force F is not infinite. The largest possible force in the entire universe is known to be the Planck force:

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

Gravitational processes inside a celestial body and even in its center can no longer be described by Newtonian physics, as the limit of its validity has been exceeded in this case. Instead, the metric equations of spacetime, which are described in Albert Einstein's theory of general relativity, must be used. This means that one has to switch from classical mechanics to relativistic mechanics.

Concepts such as inner and outer event horizon, inner and outer ergosphere, circular and point singularity, rotating and non-rotating black hole gravitational field and stationary orbit are used when considering construction of a black hole. These aspects are described by mathematical expressions. These expressions can be derived from the equation seen in the Schwarzschild metric:

$$r^2 = \Lambda = r^2 + a^2 cos^2\theta$$

or

$$r^2 = r^2 + a^2 cos^2\theta$$

We will show this briefly as follows. The length of a path in space is shown by the Pythagorean theorem:

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

If we consider the equation for radius r:

$$r^2 = x^2 + y^2$$

and the polar coordinate of the z-coordinate:

$$z = rcos\theta$$

or

$$z^2 = r^2 cos^2\theta$$

then we obtain the expression:

$$r^2 = r^2 + r^2 cos^2\theta$$

which was presented above and which is also used below. However, the relation:

$$a^2 = x^2 + y^2$$

shows that $r = a$, then we can write this equation in the following form:

$$r^2 = r^2 + a^2 cos^2\theta$$

It was seen above that the following equation holds:

$$r = a = \frac{J}{Mc} = \frac{J}{p}$$

This is essentially an expression for the angular momentum J:

$$pr = J$$

which is derived from classical mechanics. Let's move one member in the equation for r^2 to the other side of the equal sign:

$$r^2 - a^2 cos^2\theta = r^2$$

and take a square root of both sides of the equation:

$$\sqrt{r^2 - a^2 cos^2\theta} = r$$

The resulting expression is important for the following analysis. However, let's go back to the original equation for a moment:

$$r^2 = r^2 + a^2 cos^2\theta$$

If $cos^2\theta = 1$, then the equation would be in the following form:

$$r^2 = r^2 + a^2$$

Since the following equation applies above:

$$r = a = \frac{J}{Mc}$$

then, therefore, we can write:

$$r^2 = r^2 + r^2$$

Let’s divide both sides by r:

$$r = r + r$$

and we move one member to the other side of the equal sign:

$$r - r = r$$

We derived such an expression above:

$$\sqrt{r^2 - a^2} = r$$

in which the angular function can be equal to one. However, now we can write it in the following form:

$$\sqrt{r^2 - a^2} = r - r$$

or

$$\sqrt{r^2 - a^2} + r = r$$

or

$$r = r + \sqrt{r^2 - a^2}$$

These constants are present in the equation for the Schwarzschild radius r:

$$r = \frac{2G}{c^2} m$$

Therefore, it is sometimes presented without constants: $r \sim m$, which results from the choice of dimension. This gives us the equation in the following form:

$$r = m + \sqrt{m^2 - a^2}$$

Such an expression describes the outer horizon of events:

$$r_+ = m + \sqrt{m^2 - a^2}$$

or the inner event horizon:

$$r_- = m - \sqrt{m^2 - a^2}$$

If the angular function is also taken into account, this expression can also describe the outer ergosphere:

$$r_E^+ = m + \sqrt{m^2 - a^2 cos^2\theta}$$

or the inner ergosphere:

$$r_E^- = m - \sqrt{m^2 - a^2 cos^2\theta}$$

Circular and point singularities are already described by the usual radius equation known from mathematics:

$$x^2 + y^2 = a^2$$

or

$$r^2 = x^2 + y^2$$

where it can be clearly seen: $a = r$. In this case: $z = 0$. The region of change of the angular function must be taken into account above: $\theta = 0, \pi$.

To derive the equations describing the construction of a black hole, we had to use a different dimension in the Schwarzschild radius equation:

$$r = \frac{2Gm}{c^2} \sim m$$

This means that we could leave out all the constants. However, here it is worth noting one interesting coincidence. However, if we leave one non-physical constant in (the rest are physical constants), we get the following result:

$$r = \frac{2Gm}{c^2} \sim 2m = m + m$$

We can write the equation presented above

$$r^2 = r^2 + a^2 cos^2\theta$$

in the following form:

$$r^2 = r^2 + r^2$$

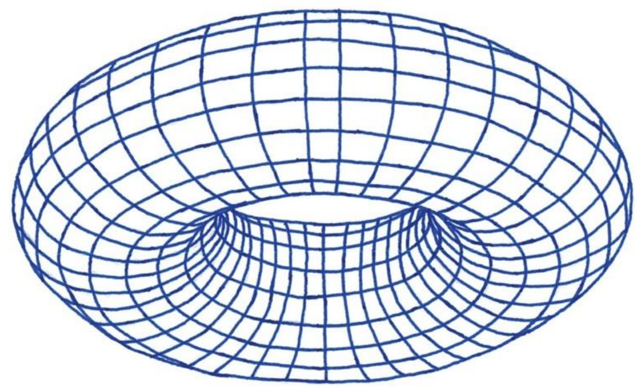
since $cos^2\theta = 1$ and $a = r$. If we divide both sides of the latter equation by r, we get:

$$r = r + r$$

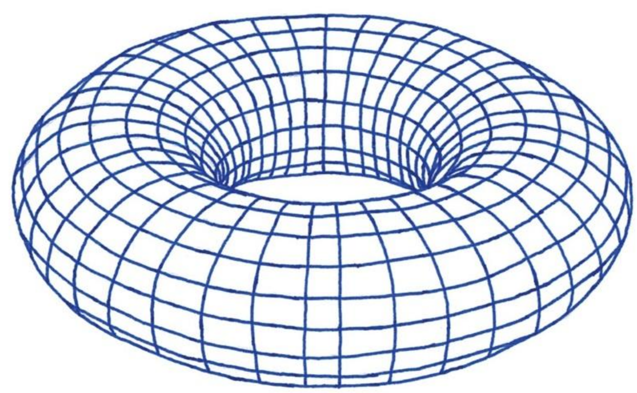
Such a result completely coincides with the expression obtained above:

$$r = m + m$$

in which case it can be seen that $r = m$.



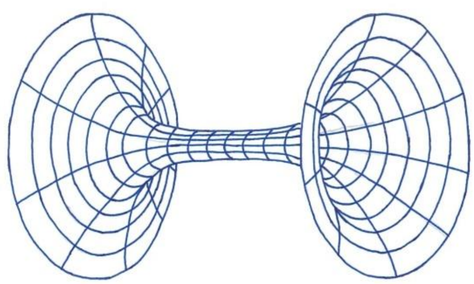
Wormholes



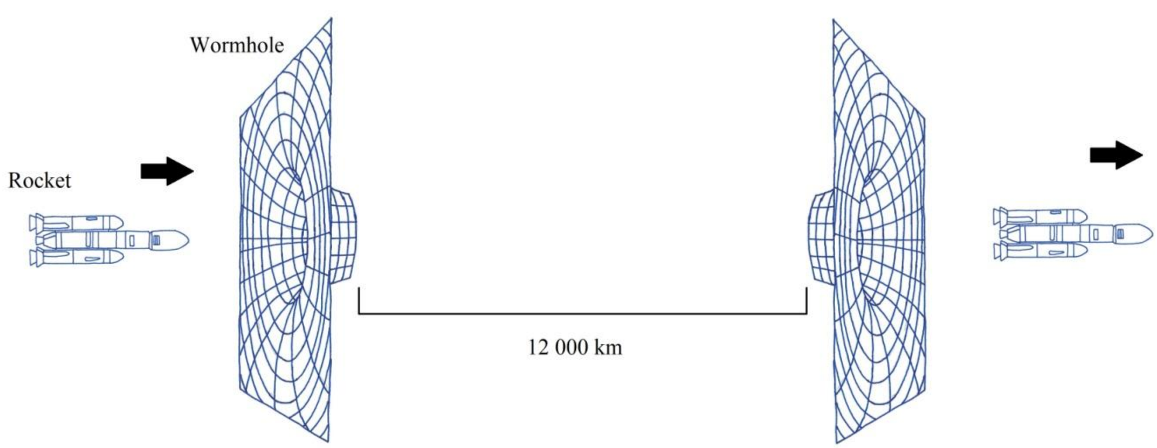
2 Wormholes: an introduction to the physics of wormholes

For a long time, the development of physics was stuck in the seeming mysticism of quantum mechanics and the theory of relativity. The theory of time-travel is a continuation of these two theories and also combines them. This has also been implied in the magazine *Imeline teadus* (No. 10/2014, page 88-95), which writes (3): ‘*After years of research, physicists have still not been able to join together the two theories (theory of relativity and quantum mechanics), which are the basis of modern physics, but the solution to the mystery might be hidden in the question of time-travel.*’ Creating a time-machine is as important for the future development of physics as was discovering that the speed of light in vacuum is constant at the end of the 19th century. It is very important to understand the physical nature of the Universe and this is revealed particularly in the theory of time-travel.

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. Figure:



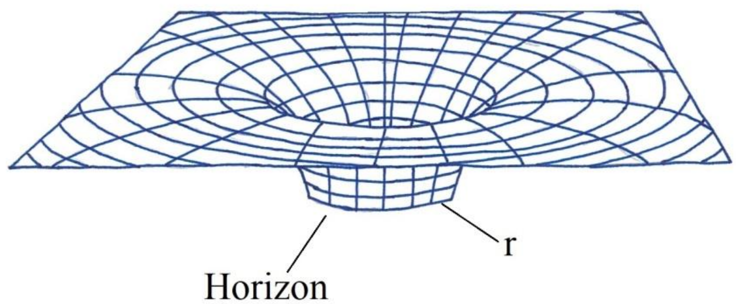
Similarly, wormholes also assist in performing space travel, since travelling through tunnels in spacetime brings extreme distances in space much closer to us. Figure:



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. For example, a black hole can at the same time be the entrance and exit of a tunnel in spacetime. Reputedly, gravity is a curvature of spacetime and on the Schwarzschild surface, in the centre of black holes, spacetime has bent infinitely. Figure:



The Schwarzschild surface of a black hole or a trapped surface in spacetime is therefore, figuratively speaking, the border of spacetime, where the existence of time and space actually ends. By now, a novel physical theory has been developed, which proves that the surface on which time and space have bent infinitely can physically be interpreted also as an entrance and exit of a tunnel in spacetime. According to this, it can be said that due to the existence of black holes, tunnels in spacetime also exist in the universe.

> A black hole can be interpreted as a wormhole, also known as a tunnel in spacetime, since the „hole“ has an entrance and an exit. For example, many scientists have „hypothetically“ stated that in addition to black holes, white holes can also exists in the universe.

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. Figure:

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.

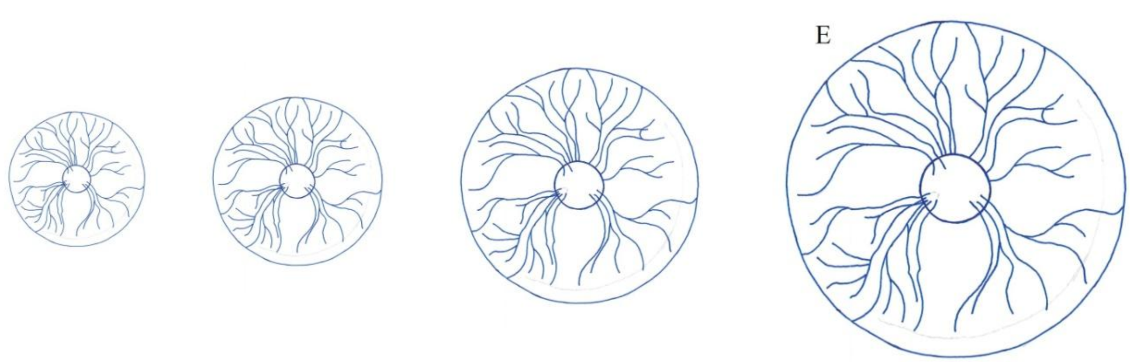
The question now lies in how humanity could be able to artificially create these miraculous tunnels in spacetime, which allow human beings to travel in time and teleport in space? By now, this question also has an answer. Firstly, creating and using black holes is not practically possible, since these are obviously dangerous for out planet and bodies close to the black hole. Reputedly nothing, not even light, can escape the centre of a black hole. The creator of a black hole is enormous mass. According to the principle of equivalence of mass and energy of Albert Einstein's theory of special relativity, a black hole as well as a tunnel in spacetime can be created with energy. However, the trouble is that a tunnel in spacetime penetrable for a human being can only be created with excessive energy and such energy cannot be taken from anywhere. There lies the main difficulty concerning creation of tunnels in spacetime. In comparison, it can be brought out that creating an „object" the size of a tunnel in spacetime penetrable for a human being would require much, much more energy that the amount of energy corresponding to the total mass of the planet Earth.

In order for spacetime to bend, a substantially strong electric charge is required, but the electric charge of a body cannot be indefinitely big, since in this case repulsive forces would start to appear between charges, which would prevent bending of spacetime. Similarly, electrical capacity of a body does not allow to hold indefinitely large charge as well. For example, on a capacitor or in the space between two surfaces charged with unlike charges the energy of an electric field is very small (likewise, field potentials are also very small), but at the same time very large electric charges and field strengths exist. For example, if the capacitance of a capacitor is 0,6 mF and its charge is 0,12 C, the capacitor „only" has 12 J of energy.

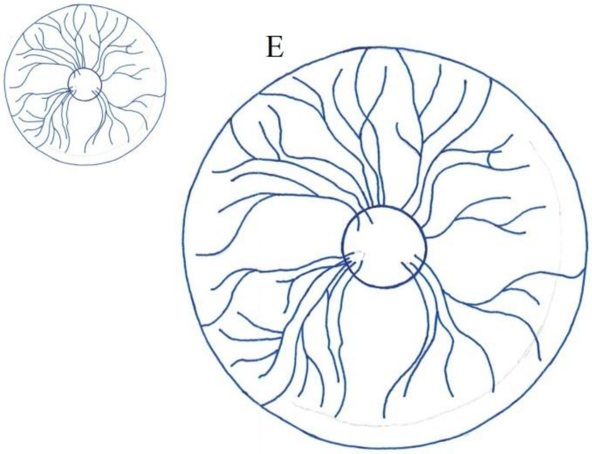
Let us assume that the electric charge of some body creates a horizon similar to a black hole with a 1 meter radius. If we perform calculations according to the equations of the theory of relativity, we get that the strength of charge q is $1{,}16 * 10^{17}$ coulombs C, if the radius r is 1 meter and permittivity ε is approximately 1. Such a charge q creates a field, which's energy would be $E \approx 10^{44}\,J$, in space. Such energy cannot be taken from anywhere or created artificially. Therefore, „in this way" it is not actually possible to create tunnels in spacetime through which it would be possible to move in time.

The size (radius R) of a body carrying the charge calculated in this way (10^{17} coulombs) must be many times larger than planet Earth. Such a charge would not stay on the surface a body of smaller size (for example a human being), since in this case repulsive forces between charges would start to have an effect.

For example (4), in 2019 the energy production/usage of the entire world was 158 800 TWh or 158 800 000 000 000 kWh. Since in physics kilowatt hour is a multiplied unit of watt second, we can present the size of such energy in joules: $E = 5{,}7168 * 10^{20}\,J$. Figure:



However, during the years 1800 – 2019, the whole energy production/usage was approximately 7 800 000 TWh or 7 800 000 000 000 000 kWh, which equals $E = 2{,}808 * 10^{22}\ J$ in joules. Figure:



Such amount of energy is not enough to create a proper wormhole, since approximately energy in the magnitude of $10^{44}\,J$ would be required to create a human-sized tunnel in spacetime, but it is not possible to take it from anywhere or produce it.

Since quantities of energy corresponding to the mass of planets cannot be produced or used, the only remaining possibility is to use minimal energies, which is clearly already within the limits of current technical capabilities of mankind.

For a long time, the problem with energy was the biggest obstacle in creating tunnels in spacetime. However, by now novel discoveries in theoretical physics have found an entirely new way to solve this problem in practice.

> For example, wormholes cannot be created with high energy, since this high energy cannot be taken from anywhere. Instead, the solution can be found in the speed of creation/changing of electromagnetic field, not so much in the level of energy anymore. There lies the novel solution. High energy bends spacetime, but the creation/changing of a field at the speed of light c also bends spacetime.

For example, in order to create a human-sized surface of a black hole or a Schwarzschild surface, it is not necessary to have excessive mass M or energy E, which actually is not possible at all. In order to create a human-sized Schwarzschild surface, the speed of change of energy field c, which can already be created artificially, is enough, whereby independent of the shape of the trapped surface of spacetime.

Creation of a field in the surrounding space required certain time. This means that if the source of the field (for example an electric charge) changes, the field also changes at a certain distances from the charge and it takes time. The changes in the field are transmitted to the whole surrounding space at the speed of light c, which means that the spatial transmission speed of the change of the field is equal to the speed of light c. The field as well as the change of the field spreads in space at the speed of light c. From this, it follows that, for example, the speed of propagation of the impulse of an electric field corresponds to the speed of light c.

In case of change in any energy field, a brief “trapped surface in spacetime” also appears, in which time and space have transformed or bent to infinity according to the theory of special relativity. Such a statement requires closer explanation. For example, while a magnetic field is created in empty space at the speed of light c, the temporary “borderline” between empty space and energy field can in principal be interpreted as a two-dimensional “surface” in which time and space have transformed to infinity, since it “moves” (“propagates”) in space at the speed of light c.

For example, for a Schwarzschild surface at the centre of a black hole or the „horizon“ of a black hole, time and space have also transformed or bent infinitely. The Schwarzschild radius r of a black hole determines the size S of Schwarzschild surface.

> "In the centre of a black hole lies Schwarzschild sphere or surface". This means that the „sphere is located in the central part of the black hole“ approximately like „ in the centre of the Galaxy, there lies a huge black hole“.

From this it follows that for example in case of creation of magnetic field, a „trapped surface of spacetime“ is also temporarily created, which can physically also be interpreted as a hole in spacetime, which in turn is the entrance and exit of a tunnel in spacetime or wormhole.

A hole in spacetime can also be seen as an opening or „door“ or „window“, through which it is possible to „enter“ hyperspace. This means that if a human being has got into a hole in spacetime, then the human has also got into the dimension of hyperspace through it. The same principle applies in case of artificial creation of a hole in spacetime.

> If we use the term „hyperspace“, it would also be logical to use the term „hypertime“. The substance of the hyperspace term is in this case clearly understandable, however, a question arises concerning what is then „hypertime“? This kind of question can be answered so that hyperspace and hypertime are in this case „synonymous“. Both of them represent a dimension in which it is possible to travel in time.

In case of time travel, the trapped surface of spacetime must be created so that it „covers“ the whole physical body. If a physical body is surrounded or covered by a trapped surface of spacetime, the body is no longer „in contact“ or interacting with the surrounding spacetime and absolutely everything else that exists in time and space. Therefore, it can be said that a body exists in hyperspace or outside spacetime, „where“ neither time nor space no longer exists.

The trapped surface of spacetime is the boundary of time and space, where the spacetime we daily experience ends (or ceases to exist). A trapped surface of spacetime can be open or closed. A trapped surface of spacetime is, for example, the „surface“ of a hole in spacetime.

> A trapped surface of spacetime can only be open or closed. For example, the surface of a sphere is a closed surface, because the body inside of it is completely covered by a spherical surface. However, an open surface can, for example, be a ring, square or rectangle, because these are two-dimensional surfaces in three-dimensional space, which does not allow covering the whole surface area of any other body. A closed surface can, for example, arise in case of two layers with unlike charges of a spherical capacitor, but an open surface can arise in case of a plate capacitor. The space between two layers of a spherical capacitor with unlike charges is closed, but in case of a plate capacitor, this space is open.
>
> In case of a physical body travelling in time, the hole in spacetime does not appear within the volume of the body itself (i.e. inside the body), but the trapped surface of spacetime „covers“ the whole surface area of the body. Therefore, the created trapped surface of spacetime is closed (and usually has the shape of the body), in the „volume" inside of which the physical body exists. Basically, this means that a physical body is surrounded by (i.e. „covered“ by) a trapped surface of spacetime, which is closed.
>
> A closed trapped surface exists naturally for example in the centres of black holes. The

size of it is determined by the mass of the black hole. In case of a closed trapped surface, a body travels in time, because a closed trapped surface is essentially a hole in spacetime.

If a physical body is covered by a closed trapped surface, then, in principal, this body exists in a hole in spacetime, through which the body enters hyperspace. In hyperspace, one moves in time.

2.1 Formation of the surface of a black hole in an electric field

Central symmetric electric field is described by, for example, the equation for the electric field strength:

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r^2}$$

Since the field is in this case central symmetric, the given equation contains

$$E = \frac{q_1}{\varepsilon_0 S}$$

equation for the surface of a sphere S:

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

if charge q_1 changes into charge q_2:

$$E = \frac{q_2}{\varepsilon_0 S}$$

in which case:

$$q_1 < q_2$$

then, therefore, the electric field surrounding the charge must also change. In this case the strength of the electric field increases.

If an electric charge changes (in this case increases), then the central symmetric electric field surrounding the charge also changes. However, the formation of a stronger field in space surrounding the charge requires certain time. This means that the speed of spatial transfer of change of an electric field is equal to the speed of light c. The field as well as the change of the field propagates in space at speed c, which means that when the source of the field (an electric charge) changes, it takes some time for the field to change as well at certain distance from the charge. For example, the propagation speed of an electric field impulse corresponds to the speed of light c, which means that changes in the field are carried over to the whole surrounding space at the speed of light c. This is proven, for example, by the fact that the speed of light c is connected to the electric and magnetic constant:

$$\frac{1}{c^2} = \varepsilon_0\mu_0 = \frac{4\pi * 10^{-7}\,\frac{N}{A^2}}{4\pi * 9 * 10^9\,\frac{Nm^2}{(A*s)^2}} = \frac{1}{9 * 10^{16}\left(\frac{m}{s}\right)^2}$$

In the latter expression, the units convert more precisely:

$$\frac{4\pi * 10^{-7}\,\frac{N}{A^2}}{4\pi * 9 * 10^9\,\frac{Nm^2}{(A*s)^2}} = \frac{4\pi * 10^{-7} N(A*s)^2}{4\pi * 9 * 10^9\, NA^2m^2} = \frac{4\pi * 10^{-7}\, A^2s^2}{4\pi * 9 * 10^9\, A^2m^2}$$

or

$$\frac{A^2s^2}{A^2m^2} = \frac{A^2}{A^2\,\frac{m^2}{s^2}} = \frac{C^2s^2}{C^2s^2\,\frac{m^2}{s^2}} = \frac{C^2}{C^2\,\frac{m^2}{s^2}} = \frac{q^2}{q^2c^2} = \varepsilon_0\mu_0$$

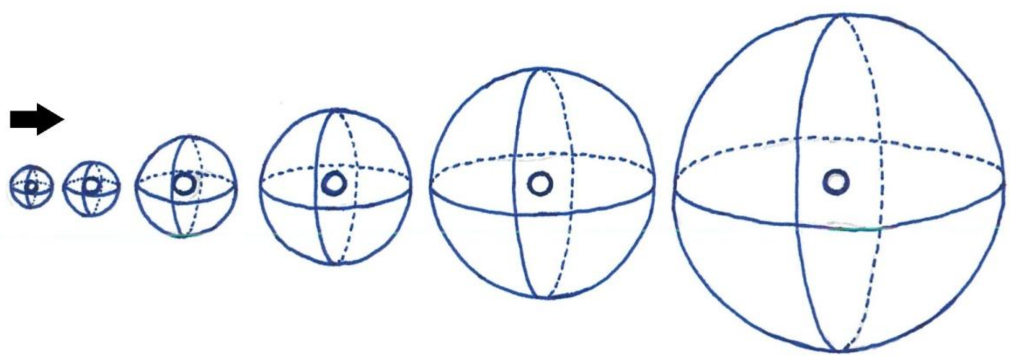
in which

$$\frac{q^2}{q^2c^2} = \frac{1}{c^2} = \varepsilon_0\mu_0$$

or

$$\frac{1}{\sqrt{\varepsilon_0\mu_0}} = c$$

Propagation of a changing electric field is mediated by magnetic field. For example, the change in an electric field at one point firstly causes a changing magnetic field and the change in this magnetic field causes (through electromagnetic induction) a change in the electric field at a neighbouring point. This means that any change in electric or magnetic field propagates in space as waves. This emerging wave is indeed an electromagnetic wave or, therefore, an electromagnetic field. From this, it follows in turn that a changing electric charge creates a „short-term“ „spherical“ electromagnetic wave or electromagnetic field surrounding the charge, which is moving away from the charge or kind of „expands“ away from the charge at the speed of light c:



A change in an electric field gives rise to the creation of a magnetic field. This means that the change of the potential φ of an electric field in time t gives rise to magnetic induction B and this happens exactly at the speed of light c:

$$\frac{\varphi}{t} = B$$

The latter expression has been derived and also proven already above. According toi t, the potential φ of an electric field is connected to the electric field strength E_T in the following way:

$$\frac{\varphi}{t} = B = K\frac{I}{d} = \frac{F}{Il} = \frac{F}{q}\frac{t}{l} = \frac{F}{q}\frac{1}{v} = \frac{F}{q}\frac{1}{c} = E_T\frac{1}{c}$$

Since we previously got the magnetic induction B as well:

$$\frac{\varphi}{t} = E_T\frac{1}{c} = B$$

we can get from the following relation:

$$E_T = Bc$$

the expression for the electric field strength:

$$\frac{\varphi}{l} = \frac{\varphi}{ct} = E_T = Bc$$

from which can be seen the relation of the change of an electric field potential φ in time t:

$$\frac{\varphi}{t} = Bc^2 = E_T c$$

so

$$\frac{\varphi}{t} = E_T c$$

Such a relation can also be derived purely from the expression for the electric force F:

$$F = k\frac{q^2}{r^2}$$

since the equation for the electric field potential φ, which can in turn be derived from it:

$$\frac{F}{q}r = k\frac{q}{r} = \varphi$$

gives us the expression for the change of potential, if we divide both sides of the equation by time t:

$$\frac{F}{q}\frac{r}{t} = E_T v = E_T c = \frac{\varphi}{t}$$

This is the following expression of a differential equation:

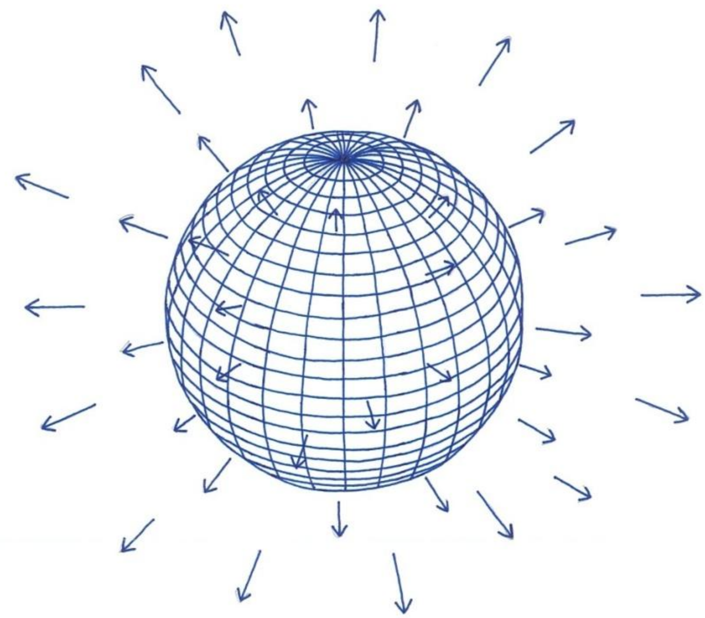
$$\frac{1}{c}\frac{\partial\varphi}{\partial t} = -divA$$

which also appears in the well-known Maxwell equations. Such coincidence does indeed prove the validity of the equations presented above.

Since the field surrounding a charge also changes due to the change in charge, the change in the field originates from the charge, which propagates away from the charge in space. The farther the change in the field propagates from the charge, the larger the radius r, due to which the surface area S is also larger:

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

Since the change in field propagates in space exactly at the speed of light c, the surface area S also "increases" exactly at the speed of light c:



$$S = 4\pi c^2 t^2$$

Therefore, in case of this “surface”, time (and actually space as well) have been altered to infinity

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

exactly like time (and space) have been altered to infinity in case of Schwarzschild surface at the centre of the gravitational field of a black hole, the size of which is determined by the equation for the Schwarzschild radius R:

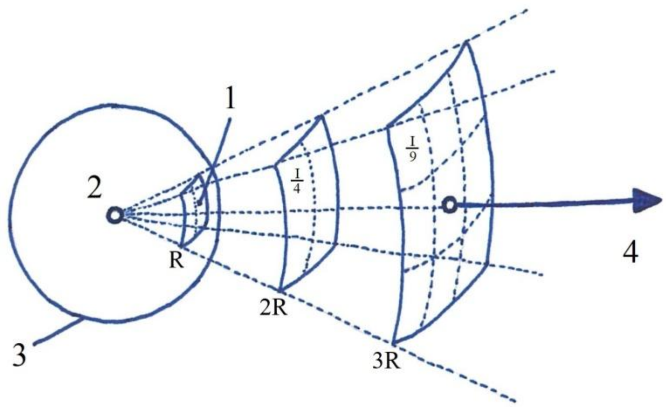
$$t` = \frac{t}{\sqrt{1-\frac{c^2}{c^2}}} = \frac{t}{\sqrt{1-\frac{2GM}{c^2R}}} = \frac{t}{\sqrt{1-\frac{R}{R}}} = \infty$$

The Schwarzschild surface of a black hole is also called a trapped surface in spacetime. The interval of spacetime is equal to exactly zero on the Schwarzschild surface of a black hole:

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

From all of this, it follows that due to the brief existence of an electromagnetic field surrounding a charge, a charge is also briefly surrounded by “a trapped surface in spacetime”, which can, according to the preceding analysis, be interpreted as “a hole in spacetime”, which can in turn be the entrance or exit of a tunnel in spacetime or wormhole.

In case of change of any energy field, a brief “trapped surface in spacetime” also appears, on which time and space have transformed or bent to infinity according to the theory of special relativity. Such a statement requires further explanation. For example, if a electric field is generated in empty space at the speed of light c, then the temporary "borderline" between empty space and an energy field can notionally be interpreted as a two-dimensional "surface" on which time and space have transformed to infinity, because it "moves" ("propagates") in space at the speed of light c. This means that this surface increases in time at the speed of light c. The figure (exemplified by a charged sphere):



1. Intensity: $I = \frac{W_{EM}}{S}$
2. Source power: W_{EM}
3. Imaginary sphere area: $S = 4\pi R_0,\ R_0 = R, 2R, 3R$ ...
4. Direction of propagation of EM wave

Time has transformed into infinity on the short-term abstract surface that has arisen:

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

and lengths have contracted to zero:

$$l' = l\sqrt{1 - \frac{c^2}{c^2}} = 0$$

since the surface increases in time at the speed of light c. This is similar to the expansion of a sphere in space at the speed c. Consequently, the body cannot be "in contact" with the rest of the universe, if such a surface would cover the body, i.e. if the body were inside a sphere that would expand at the speed of light c. In this case, the body is outside spacetime, which in turn means that the body exists in hyperspace in our sense.

After all, it can be argued that a body that exists inside a spherical surface actually also exists in spacetime, since a spherical surface has dimensions in space and time of existence. This understanding is actually not quite correct. A spherical surface exists in spacetime because it has spatial dimensions and a temporal existence, but the sphere expands exactly at the speed of light c, so time and space are transformed to infinity on its surface. Therefore, the body inside the sphere can no longer exist in spacetime, even though the sphere itself has instantaneous dimensions in time and space.

However, it can also be argued that a body that exists within a spherical surface actually exists in spacetime as well, since a body has spatial dimensions and an existence in time. This understanding is also not really correct. A body does indeed have spatial dimensions and a temporal existence within a spherical surface, but the sphere expands in spacetime exactly at the speed of light c, so time and space are transformed to infinity on its surface. The infinite transformation of time and space means physically that time and space cease to exist. Therefore, a body inside a spherical surface can no longer exist in relation to the surrounding spacetime, even though the body itself has temporal and spatial dimensions. This means that within a spherical surface, time and space exist only relative to the body itself.

A black hole has no physical surface, because the gravitational field is not an energy field in nature. An abstract surface called the "trapped surface in spacetime" is formed by the infinite transformation of spacetime. However, in case of an energy field changing at the speed of light c, there is also a physical surface in addition to the abstract surface, since the field has energy. In this case, both the trapped surface in spacetime and the physical surface exist at the same time, in which case the trapped surface in spacetime also has a physical surface. This is because the field has energy.

In case of central symmetric strength of an electric field:

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r^2}$$

in the given equation

$$E = \frac{q_1}{\varepsilon_0 S}$$

appears precisely the equation for the surface area S of a sphere:

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

The surface of a sphere is a closed surface, since the body inside of it is completely covered by the spherical surface. However, an open surface can, for example, be a circle, square or rectangle, because these are two-dimensional surfaces in three-dimensional space, which does not allow covering the whole surface of another body. A trapped surface in spacetime can be either open or closed.

The field must change around the charge "everywhere at the same time", not so that the field changes in one point of the field sooner and in another point of the field of the charge a bit later. Only in this case a charged body is surrounded or covered by precisely a "closed" trapped surface in spacetime, since in this case the charged body would no longer be "in contact with" or interact with the surrounding spacetime and absolutely everything else that exists in time and space. Therefore, it can be said that a body exists in hyperspace or outside spacetime, "where" neither time nor space no longer exist. A trapped surface in spacetime is a "borderline" between time and space, where the spacetime we routinely experience "ends" (or ceases to exist).

On the other hand, however, an open surface does not cover the whole surface area of any other body. In case of an open surface, the body does not travel in time, because it does not cover the whole surface area of the body and, by virtue of this, the body does not go into hyperspace or it maintains "contact" with the surrounding spacetime. An open surface can partly cover the surface area of another body. This means that in case of a closed surface the coverage is full (100%), but in case of an open surface, the coverage is only partial (not 100% any more).

2.2 The field of an electrically charged sphere

In the following, we present an "idealized example, or physical model" of an electrically charged sphere, or sphere, in which a person can fit and which is charged from within the sphere. The sphere does not rotate, spin or move in space. Such an illustrative model shows very clearly how a trapped surface in spacetime is formed from electromagnetic interactions, as a result of which it is possible to create artificial tunnels in spacetime, or wormholes.

In case of the electrically charged sphere model, we are dealing with a spherical surface S charged with a uniform surface density σ. Such a sphere with a radius R creates a centrally symmetric energy field in the surrounding space, which means that at every point in space the target vector of the electric field E passes through the centre of the sphere. The field strength depends on the distance r from the centre of the sphere, and for all points on the spherical surface the vector E is: $E_n = E(r)$. However, if the value of r is greater than the value of R, then in this case the charge q remains inside the spherical surface. The charge q on the sphere creates the entire energy field. Spherical surfaces r smaller than the radius R of the spherical surface do not contain electric charges, and thus there is no field inside the charged spherical surface. However, there is a field outside the spherical surface, and it is similar to the field of a point charge of the same magnitude placed at the centre of the sphere. In case of an electrically charged sphere, the electric field potential φ always decreases when moving away from the surface of the sphere, as a result of which the electric force of the charged sphere also decreases. For example, to move an electric charge q over a distance dr outside a charged sphere, the work of the field forces can be expressed as follows:

$$dA = qE_r dr$$

At the same time, the work of the field forces can also be expressed as a decrease in the potential energy of the charge q, or:

$$-d(q\varphi) = -q\frac{\partial\varphi}{\partial r}dr$$

Thus, the last two expressions are equal to each other:

$$qE_r dr = -q\frac{\partial\varphi}{\partial r}dr$$

i.e. we get the relation

$$E_r = -\frac{\partial\varphi}{\partial r}$$

in which r denotes an arbitrarily chosen direction in spherical space that coincides with the direction of the radius of the sphere. If we multiply both sides of the latter expression by charge q, we get the following relation:

$$f_r = -\frac{\partial W_p}{\partial r}$$

in which f_r is the electric force in the direction of distance r, ∂W_p is the potential energy and ∂r, or r, denotes an arbitrarily chosen direction in a spherical or centrally symmetric space. In this way, the electric field is described by the vector E or the scalar φ, that is, there is a relationship between the two, similar to the relationship between potential energy and force. The latter expression generally indicates that the electric force as well as the potential energy of the field both decrease away from the source.

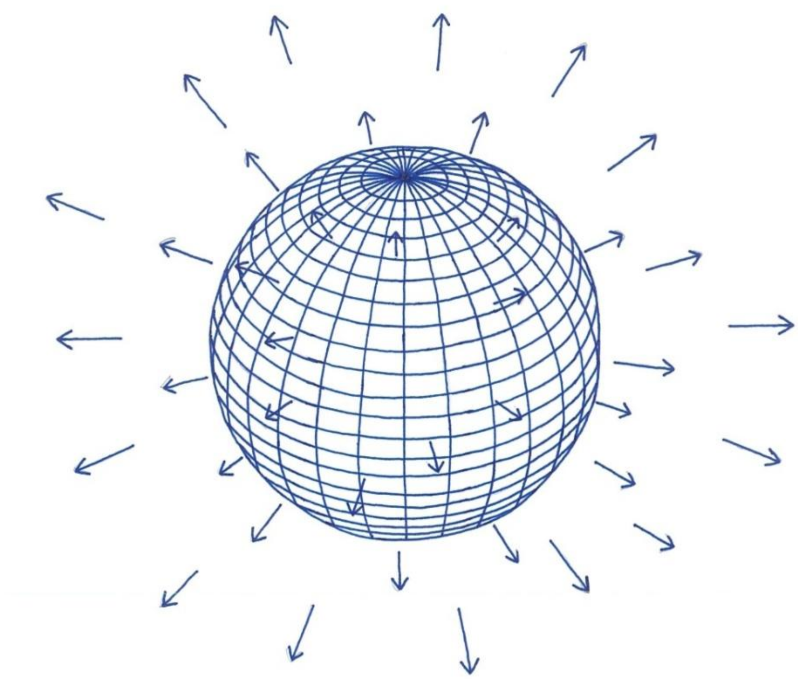


Figure: Vector field around an electrically charged sphere. There is no field inside the sphere.

The member $-\frac{\partial}{\partial r}$ in the equations can also be expressed as a negative grad, i.e

$$-\left(i\frac{\partial}{\partial x}+j\frac{\partial}{\partial y}+k\frac{\partial}{\partial z}\right),$$

which is denoted as nabla ∇. This is because the member $-\frac{\partial}{\partial r}$ is a vector the components of which are

$$\frac{\partial}{\partial x},\frac{\partial}{\partial y}\ \ and\ \ \frac{\partial}{\partial z}$$

and thus the equation

$$E_r\ =-\frac{\partial\varphi}{\partial r}$$

can be expressed as a gradient of a scalar φ as follows:

$$E=-grad\varphi$$

or

$$E=-\left(i\frac{\partial\varphi}{\partial x}+j\frac{\partial\varphi}{\partial y}+k\frac{\partial\varphi}{\partial z}\right)$$

or

$$E = -\nabla\varphi \,,$$

in which ∇ is nabla. This means that the electric field strength E is equal to the potential gradient of opposite sign. Nabla or Hamiltonian operator ∇ is a vector differential operator. It is a vector the components of which are

$$\frac{\partial}{\partial x}, \frac{\partial}{\partial y} \;\; and \;\; \frac{\partial}{\partial z}$$

and thus nabla is obtained as follows:

$$\nabla = i\frac{\partial}{\partial x} + j\frac{\partial}{\partial y} + k\frac{\partial}{\partial z}.$$

This vector alone has no meaning, but it only acquires physical meaning when multiplied by a simple scalar or vectorial function. For example, we can get the gradient of a function by multiplying the vector ∇ by the scalar φ, the result is a vector:

$$\nabla\varphi = i\frac{\partial\varphi}{\partial x} + j\frac{\partial\varphi}{\partial y} + k\frac{\partial\varphi}{\partial z},$$

in which the electric field potential φ is expressed as the following function:

$$\varphi = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

The field potential is described by a differential equation, which is the gradient or grad. The gradient is denoted by a symbol called nabla:

$$\nabla\varphi = grad\varphi$$

However, we can get the divergence of the vector A by multiplying the vector ∇ scalar by the vector A, the result is a scalar:

$$\nabla A = \nabla_x A_x + \nabla_y A_y + \nabla_z A_z = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z}.$$

We can get one component (x) of the vector rotA by multiplying the ∇ vectorially by the vector A, resulting in a vector, one component of which is, for example, the following expression:

$$(\nabla A)_x = \nabla_y A_z - \nabla_z A_y = \frac{\partial A_z}{\partial y} - \frac{\partial A_y}{\partial z}$$

∇ is a differential operator. A vector function is the gradient of some function φ. For example:

$$divgrad\varphi = \nabla(\nabla\varphi) = (\nabla\nabla\varphi) = \left({\nabla_x}^2 + {\nabla_y}^2 + {\nabla_z}^2\right)\varphi = \frac{\partial^2\varphi}{\partial x^2}\frac{\partial^2\varphi}{\partial y^2}\frac{\partial^2\varphi}{\partial z^2} = \triangle\,\varphi$$

in which △ is the Laplace operator. Accordingly, the entire electric field is described through the Poisson's equation:

$$\Delta\varphi = -4\pi\rho \quad \text{or} \quad \text{divgrad}\varphi = -4\pi\rho,$$

in which div$\vec{E} = 4\pi\rho$ and $\vec{E}$ = -gradφ. The circulation of an electric field (i.e. the electrostatic field) is zero for any contour:

$$\oint E_r\, dr = 0.$$

The latter equation is valid only for the electrostatic field and is also consistent with the following mathematical expression:

$$rotgrad\varphi = (\nabla, \nabla\varphi) = (\nabla\nabla)\varphi = 0$$

The latter expression means that the cross product of a vector with itself is zero.

However, if the electric charge of the entire sphere were to change (increase or decrease) at the same time, the centrally symmetrical electric field surrounding the charged sphere would also change (stronger or weaker, respectively). However, the emergence of a stronger or weaker field in the space surrounding the sphere requires a certain time. This means that the speed of the spatial transfer of the sphere's field change is equal to the speed of light c. The field and also the change in the field propagates in space at a speed c, that is, it takes a certain time for the field to change at a certain distance from the charge of the sphere when the source of the field (in this case the electric charge of the sphere) changes. For example, the speed of propagation of an electric field pulse matches the speed of light c, i.e. changes in the field are transmitted to the entire surrounding space at the speed of light c.

The propagation of a changing electric field takes place via magnetic field. For example, a change in the electric field at one point firstly causes a changing magnetic field, and a change in that magnetic field causes (through electromagnetic induction) a change in the electric field at a neighbouring point. This means that any change in the electric or magnetic field propagates through space as a wave. This resulting wave is an electromagnetic wave, i.e. an electromagnetic field. In turn, it follows from this that with the change in the sphere's charge, a "spherical" electromagnetic wave or electromagnetic field surrounds the sphere for a "short time", which moves away from the charged sphere, i.e. as if it "expands" away from the sphere, and which can be interpreted based on the above analysis as a photon probability wave, or a probability field, on the "surface" of which time and space have transformed to infinity.

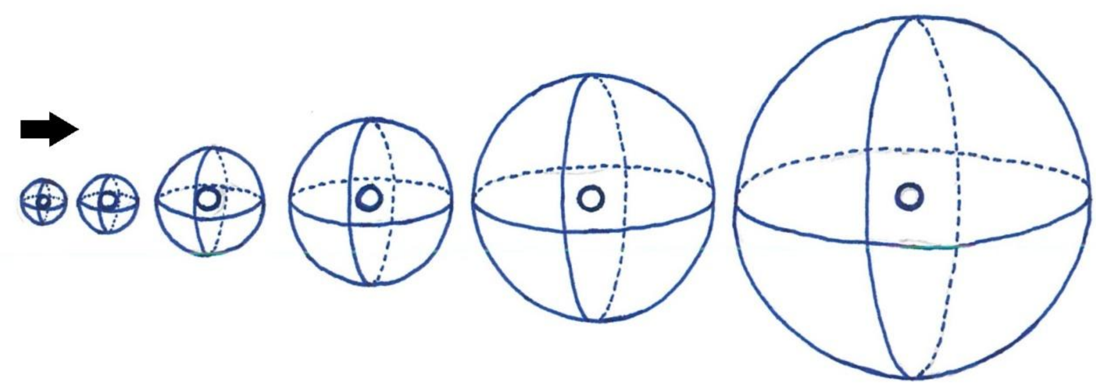


Figure: The change in an electric field of a charged sphere (dot in the figure) in the space outside the centre of the sphere occurs at the speed of light c. Visually, this is similar to the "expansion" of a change of the centrosymmetric energy field in time.

This probability wave moves away from the sphere, i.e. the surface of the spherical probability field sort of "expands" away from the charged sphere at the speed of light c. Therefore, on its "surface" time (and space) has transformed to infinity

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

just as time (and space) has transformed to infinity on the Schwarzschild surface at the centre of the black hole's gravitational field, the size of which is determined by the equation for the Schwarzschild radius R:

$$t` = \frac{t}{\sqrt{1-\frac{2GM}{c^2 r}}} = \frac{t}{\sqrt{1-\frac{R}{R}}} = \infty$$

From all of this, it follows that in case of the short-term existence of the electromagnetic field surrounding the sphere, the charged sphere is also briefly surrounded by a trapped surface in spacetime, which, based on the above analysis, can also be interpreted as a hole in spacetime, which in turn is the entrance and exit of a tunnel in spacetime or wormhole.

2.3 The formation of a black hole surface in an electromagnetic field

From the electric field strength E equation above:

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

we were able to derive a two-dimensional surface on which time and space transform to infinity. Due to the movement, this surface exists for an extremely short time. It was primarily electrostatic physics, in which the existence of surfaces for the creation of artificial wormholes was observed. However, such surfaces actually also exist in case of an electromagnetic field, in which there is also a magnetic field in addition to the electric field. We will show this in the following. From the equation for the electric field strength E, we get the expression for the electric field potential φ:

$$Er = \frac{1}{4\pi\varepsilon_0}\frac{q}{r} = \varphi$$

The electric field potential φ is proportional to the electrostatic force F:

$$\varphi = F\frac{r}{q}$$

We can express the coordinate r as the product of speed and time: ct. Due to this, we can transform as follows:

$$\varphi = F\frac{1}{q}ct = F\frac{t}{q}\frac{l}{t} = \frac{Fl}{I}\frac{1}{t}$$

Since the obtained equation contains electric current I, which is already accompanied by magnetic phenomena, then instead of electrostatic force F, we can now consider magnetic force F instead. As a result, we got such a quotient, which is equal to the concept of magnetic flux known in physics (in units):

$$\frac{Fl}{I} \to \frac{1N * 1m}{1A} = \frac{1N}{1A * 1m} 1m^2 = 1T * 1m^2 = 1Wb$$

or

$$1T * 1m^2 = 1Wb$$

Instead of units, we write out their corresponding values:

$$BS = \Phi$$

This is the definition of magnetic flux, where S is the surface area and B is the magnetic induction. If the magnetic flux is divided by the time period t:

$$\frac{1Wb}{1sek} = 1V$$

then we get Faraday's law of induction:

$$\varepsilon_i = \frac{\Delta\Phi}{\Delta t}$$

which is one of the fundamental equations of the physics of electromagnetism. Such a quantity describes the rate of change of the magnetic flux and its unit is volt V. It turns out that such a unit matches the unit of the electric field potential derived above:

$$\varphi = \frac{Fl}{I}\frac{1}{t}$$

For example, the unit of electric field potential is energy divided by charge:

$$\varphi = \frac{E_p}{q} \to \frac{1J}{1C}$$

and the unit of voltage is actually also energy divided by charge:

$$U = \frac{A}{q} \to \frac{1J}{1C} = 1V$$

then, as a result, we also get the 1V as the unit of electric field potential:

$$\varphi \to 1V$$

which also matches the unit 1V of the obtained electromotive force ε_i. The "derivation" of the expression of the magnetic flux and its rate of change from electrostatic physics shows quite clearly that such surfaces on which time and space transform to infinity also occur in the case of an electromagnetic field, not only in the case of an electric field. In the case of an electromagnetic field, we have to consider the magnetic field in addition to the electric field and also the transformation of these two into each other. In the following, we will thoroughly analyze and define all this.

There is a magnetic force F between two parallel sections of wire:

$$F = K\frac{I_1 I_2}{d} l$$

where K is the constant $K = \frac{\mu_0}{2\pi}$, d is the distance between the wires, l is the length of the wires and I_1 and I_2 are the currents in the wires. In the last formula, the magnetic induction B is manifested as follows:

$$B = K\frac{I}{d}$$

due to which we can write Ampere's law:

$$F = BIl\ sin\alpha$$

If the magnetic field is perpendicular to the direction of the current, we can write:

$$F = BIl$$

It is a magnetic force F that acts on a current-carrying wire in a magnetic field. From classical mechanics, we know that the product of force F and distance b is the basis for the definition of work A:

$$A = Fb$$

In this case, the angle is equal to one: $cos\alpha = 1$. The latter equation means that work is done when a force acts on a body and the body moves under the influence of that force. Using this definition, we get the work A done by the magnetic force F to move the wire through a distance b in the magnetic field:

$$A = Fb = BIlb = BIS$$

In the latter expression there is an area: $l * b = S$. It results from the product of the length l of the wire itself and the distance b traveled in space. According to this, we can arrive at the concept of magnetic flux:

$$\frac{A}{I} = BS$$

The magnetic flux Φ indicates the extent to which the magnetic field lines pass through the observed surface due to the size and position of that surface in the magnetic field:

$$\Phi = BS\ cos\beta$$

The magnetic flux indicates the number of lines of force passing through the surface. If $cos\beta = 1$, we can write:

$$\Phi = BS$$

In this case, the largest number of lines of force pass through the surface. From the definition of magnetic flux $\Phi = BS$, we in turn get the fundamental law of electromagnetic induction, i.e. Faraday's law of induction:

$$\varepsilon_i = -k\frac{\Delta\Phi}{\Delta t}$$

This expression means that the electromotive force of induction is proportional to the rate of change of the magnetic flux. The induction current and the corresponding electromotive force ε_i are greater the faster the magnetic field changes. In the SI system, it has the following form:

$$\varepsilon_i = -\frac{\Delta\Phi}{\Delta t}$$

since k = 1. One weber is such a change in magnetic flux that, occurring in one second, produces one volt of induction electromotive force (1 Wb = 1 V * 1 s):

$$\Delta\Phi = -\varepsilon_i \Delta t$$

The minus sign indicates the direction of the change taking place. In Faraday's law of induction

$$\varepsilon_i = -\frac{\Delta\Phi}{\Delta t}$$

the minus sign actually expresses Lenz's rule. According to Lenz's rule, an induced current always acts opposite to the cause that induces the current. Induction current always favors the preservation of the existing situation.

EXAMPLE. Suppose we are dealing with a coil of wire consisting of 400 turns and whose resistance to direct current is 4 Ω. There is a tester attached to the ends of the coil, which operates in the measurement range of 100 mV and has a resistance of 1 kΩ. The pointer of the tester deviates to a value of 10 mV when a permanent magnet is inserted into the coil for one second. The cross-sectional area of a permanent magnet is 0.5 cm^2. In this case, the coil is a current source with internal resistance r = 4 Ω. The resistance of the tester 1 kΩ is the external resistance R. In this case, the terminal voltage U is equal to the electromotive force ε_i, since the external resistance R is much higher than the internal resistance r. Turns can be seen as current sources connected in series. Faraday's law of induction can be written here without a minus sign:

$$\varepsilon_i = \frac{\Delta\Phi}{\Delta t}$$

since we are interested in the magnitude of the change, not its direction. From the above data, it can be seen that the electromotive force in one turn is manifested as follows:

$$\varepsilon_{ü} = \frac{\varepsilon_i}{N} = \frac{10mV}{400} = 25\mu V$$

According to this, we get the magnetic flux change as follows:

$$\Delta\Phi = \varepsilon_{ü}\Delta t = 25\mu V * 1s = 25\mu Wb$$

It should be noted that the initial value of the magnetic flux was equal to zero. Consequently, the final value of the magnetic flux Φ is numerically equal to the change $\Delta\Phi$. We can find the value of magnetic induction B as follows:

$$B = \frac{\Phi}{S} = \frac{25 * 10^{-6} Wb}{5 * 10^{-5} m^2} = 0{,}5\, T$$

In the latter, we see that $\beta = 0$, or $\cos\beta = 1$. This is because the magnetic field is directed along the common normal of the turns, since the magnetic field of a permanent magnet is parallel to the axis of the coil. As a final conclusion, it can be stated that the magnetic flux in one turn changed by 25 microwebers and the magnetic induction B of the permanent magnet was 0.5 tesla.

The phenomenon of electromagnetic induction also occurs in a homogeneous magnetic field. In this case, the variable quantity cannot be the magnetic induction B, but only the surface area S. This means that the electromotive force of the induction in this case depends only on the surface area S.

If we divide the change in magnetic flux by the change in current, we get the inductance L:

$$L = \frac{\Delta\Phi}{\Delta I}$$

The inductance of a conductor tells us how much change in magnetic flux is caused by a unit change in current in this conductor.

From the inductance expression:

$$L = \frac{\Delta\Phi}{\Delta I}$$

we can easily obtain an equation describing the energy of the magnetic field. For example, the range of magnetic flux is defined by the latter formula as follows:

$$\Delta\Phi = L\Delta I$$

In this case, we have to take into account that we are no longer dealing with induction electromotive force ε_i:

$$-\varepsilon_i \Delta t = L\Delta I$$

but with the electromotive force of self-induction ε_e:

$$-\varepsilon_e \Delta t = L\Delta I$$

The inductance L of the conductor indicates how strong self-induction electromotive force ε_e is generated in this conductor by a unit change of the current during a unit of time:

$$\varepsilon_e = -L\frac{\Delta I}{\Delta t}$$

In case of self-induction, the change in magnetic flux is caused by the change in current in the considered conductor itself. We multiply both sides of the latter equation with electric charge q:

$$\varepsilon_e q = -L\frac{\Delta I}{\Delta t}q$$

As a result, we get the equation describing the energy of the magnetic field:

$$W_m = LI\frac{I}{2}$$

or

$$W_m = \frac{LI^2}{2}$$

The latter equation describes the energy of a current-carrying coil. The energy of the current-carrying coil is considered in physics as the energy of the magnetic field. The equation describes the energy of a magnetic field generated in the coil. This means that if a current of strength I flows in a coil with inductance L, then the coil has energy W_m. It is also called magnetic field energy because this energy is caused by the presence of a magnetic field in a current-carrying coil.

Faraday's law of induction is based on the concept of magnetic flux. The concept of magnetic flux becomes most highlighted in the case of the movement of a section of a wire in a magnetic field. For example, suppose that a section of straight wire moves to the right with speed v and in a magnetic field with magnetic induction B. Let y be the angle between the vectors v and B. Let the length of the section of the straight wire be l. If a section of a straight wire travels a distance Δx during time Δt, an imaginary frame is formed, the area of which increases:

$$\Delta S = \Delta x * l$$

This means that the area of the imaginary frame becomes larger due to the movement of the section of the wire in the magnetic field. This in turn causes the magnetic flux to increase:

$$\Delta \Phi = \Delta x * l * B * cos\beta$$

According to Faraday's law of induction, an electromotive force of induction ε_i occurs in a moving section of a straight wire, the absolute value of which is equal to:

$$|\varepsilon_i| = \frac{\Delta \Phi}{\Delta t} = \frac{\Delta x}{\Delta t} lBcos\beta$$

or

$$|\varepsilon_i| = vlBcos\beta$$

The equation in it:

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

is equivalent to the definition of velocity from classical mechanics. If the velocity vector of the moving section of a wire lies in the plane of the frame, then it is perpendicular to the frame normal n. The angle between the vectors v and B is y, but the angle between the vectors B and n is β. It follows that the angles β and y are co-angles:

$$\beta + \gamma = \frac{\pi}{2}$$

A relation known from mathematics applies to co-angles:

$$cos\beta = sin\gamma$$

This gives us the form of the absolute value of the induced electromotive force:

$$|\varepsilon_i| = vlBsin\gamma$$

If there was no current, or $\varepsilon_i = U$, then the last expression takes the following form:

$$U = vlBsin\gamma$$

The resulting equation is obtained using the definition of the Lorentz force. A moving section of a straight wire can be seen as a section of wire cutting the lines of force of the magnetic field. The presence or absence of a frame (except for the wire section itself) is not important at all from the point of view of the induction phenomenon.

Expression of the obtained voltage U:

$$U = vlBsiny$$

shows the voltage U at the ends of the section of the wire in the absence of current. Such an equation is also obtained through the equation for the Lorentz force. For example, if the direction of movement of the wire section does not form any angle y with the magnetic field:

$$Bsiny = B_r = B$$

then thus we get the equation in the following form:

$$U = vlB$$

Let's move the product l to the other side of the equals sign:

$$\frac{U}{l} = vB$$

and multiply both sides of the equation by the electric charge q. As a result we get:

$$qvB = q\frac{U}{l} = qE = F_e$$

From the latter, it can be seen that there is an equilibrium condition $F_L = F_e$, in which the Lorentz force also exists

$$F_L = qvB$$

(in which sinα = 1) ja electric force

$$F_e = qE$$

In this case, the magnetic force and the electric force are in balance.

If the equation for the magnetic flux $\Phi = BS$ is divided by the time period t, the fundamental law of electromagnetic induction, or Faraday's law of induction, is obtained:

$$\varepsilon_i = -\frac{\Delta\Phi}{\Delta t}$$

This expression means that the electromotive force of the induction is proportional to the rate of change of the magnetic flux. The induction current and the corresponding electromotive force ε_i are the greater the faster the magnetic field changes. One weber is a change in magnetic flux that, occurring within one second, produces one volt of induction electromotive force (1 Wb = 1 V * 1 s):

$$\Delta\Phi = -\varepsilon_i \Delta t$$

A misinterpretation can occur here. Any energy field (for example, an electric field or a magnetic field) always arises or changes in time and space at the speed of light c. In Faraday's law of induction, it is also about the speed of change of the magnetic field, which, however, does not equal the speed of light c. This results from the fact that in Faraday's law of induction, the rate of change of the magnetic field is taken into account, which is caused by the movement of a physical body (for example, a section of a straight wire) in space. The speed of movement of a physical body can never be equal the speed of light c. However, the transfer rates of changes in the energy fields themselves to the surrounding space are always equal to the speed of light c. Field and matter are different forms of matter. For example, an electromagnetic wave travels in vacuum exactly at the speed of light c. This is a very important difference to consider in the physics of electromagnetism.

> For example, an alternating current pass between the plates of a capacitor by means of a changing electric field even in empty space. For example, a phenomenon in which charge carriers start to move on another plate due to the strengthening electric field of the charged plate is called shear current. The movement of charges is accompanied by a magnetic field, but it also occurs in the empty space between the capacitor plates in the absence of charge carriers. When the magnetic field changes, a solenoidal electric field is generated independently of the origin of the change. For example, when the current in the coil changes or when a permanent magnet is moved. When the electric field changes, the magnetic field also arises independently of the origin of the changing electric field. This also means that the propagation of the changing electric field takes place through the medium of the magnetic field. When an alternating current passes between the plates of the capacitor, a magnetic field occurs, the lines of force of which surround the direction of change of the electric field. The lines of force of the magnetic field are closed lines and the change in the electric field propagates in space exactly at the speed of light c.
>
> A change in the electric field creates a magnetic field, and a change in the magnetic field in turn creates an electric field. This transformation of electric and magnetic fields into each other occurs at the speed of light c, and the speed of movement of an electromagnetic wave in vacuum is also the speed of light c. An electromagnetic wave is the propagation of changes in electric field and magnetic field in space. However, an electromagnetic wave can also be seen as the motion of a quantum particle photon in vacuum, with zero mass m and an energy E expressible as the well-known Max Planck equation for the quantum energy E.

Faraday's law of induction takes into account such a rate of change of the magnetic field

$$\varepsilon_i = -\frac{\Delta\Phi}{\Delta t}$$

caused by the movement of a physical body in space. The speed of movement of a physical body with a standing mass can never be equal to the speed of light c. However, the transfer rates of changes in energy fields (such as electric or magnetic fields) to the surrounding space are always equal to the speed of light c:

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

For example, let's say we have a loop of wire with no current flowing through it:

$$I = \frac{q}{t} = 0$$

If, however, a permanent magnet passes through the circular conductor, a unit electric current is generated in the circular conductor when the permanent magnet moves from the circular conductor: $I \neq 0$. This is clearly a phenomenon of electromagnetic induction. In this case, we see that the area S formed by the circular wire does not change over time

$$\varepsilon_i = -B\frac{S}{t}$$

but the magnetic induction B changes with respect to the area S formed by the circular wire

$$\varepsilon_i = -\frac{B}{t}S$$

when the permanent magnet by its motion approaches it and finally passes through this imaginary surface. Because of this, we can talk about the change of the magnetic flux Φ during the time period t

$$-\frac{\Delta\Phi}{\Delta t}$$

that is, the rate of change of the magnetic field over a period of time. But this can only be understood in relation to the imaginary surface formed by a loop in space. It is important to note that the magnetic field of the permanent magnet itself does not change over time. The change of the permanent magnet's own field in space would already take place exactly at the speed of light c.

> At this point, it should be noted that in the case of motion of a permanent magnet, there is actually an electric field in addition to the magnetic field. This is because an observer registers a magnetic field with a stationary permanent magnet, but a moving permanent magnet also creates an electric field for the observer. The generation of an electric field when the magnetic field changes is called the phenomenon of electromagnetic induction. When the magnetic field changes, an electric field is created. It is a solenoidal electric field, the lines of force of which are closed lines. But in this case, we do not consider the change of the field of the permanent magnet itself. The permanent magnet moves in a straight line and at a constant speed.
>
> > For a stationary charged body, an observer registers an electric field, but a moving charged body also creates a magnetic field for the observer.

However, if the magnetic field changes at the speed of light c relative to the surface of a circular wire, then the permanent magnet should move through the imaginary surface formed by the circular wire apparently at the speed of light c. However, it is not feasible in reality. Another possibility would be for a permanent magnet to appear instantly (i.e. in 0 seconds) in the middle of the circular wire. In this case, the magnetic field around the permanent magnet would be created exactly at the speed of light c, due to which the magnetic field would also change at the speed c relative to the surface of the circular wire. However, such an option is also not feasible in reality.

The rate of change of the magnetic field usually means the rate of change of the magnetic flux. In Faraday's law of induction:

$$\varepsilon_i = -\frac{\Delta\Phi}{\Delta t}$$

there is a definition of magnetic flux: $\Phi = BS$, where cos β = 1 and whose unit is one weber in the SI system:

$$1Wb = 1T * 1m^2 = \frac{1N}{1A * 1m} 1m^2 = \frac{1N * 1m}{1A}$$

One weber is the magnetic flux that passes through a surface of 1 m^2 intersecting with the direction of the magnetic field, when the magnetic induction of the field is 1 T. Therefore, it cannot actually be stated that the speed of change of the magnetic field, or the speed of change of the magnetic flux, can also be equal to the speed of light c, because the units are different. It would be more correct to express it in such a way that the rate of change of the magnetic flux can be equal to the quantity at which the speed of light c occurs:

$$\frac{S}{t} = \frac{\pi r^2}{t} = \pi r * c$$

or

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

It can be seen from the latter formula that we are dealing with a circular area S. The above means that the speed of change of the magnetic flux cannot be equal to the speed of light c due to the differences in units, but it can be equal to a quantity (in webers) that contains a quantity proportional to the speed of light c. Nevertheless, there is an expression in circulation among the people that the speed of change of the magnetic flux can also be equal to the speed of light c. This simplifies the whole point above.

In case of an electric field, we can take into account the equation for the area of a sphere in mathematical calculations. For example, in the equation for the electric field strength:

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

appears the expression for the surface area S of a sphere:

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

or

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

An electric field is a centrally symmetric energy field, but a magnetic field is not centrally symmetric. The central symmetry of a magnetic field manifests itself in three-dimensional space only in one specific plane, therefore the area of the circle S can be taken into account:

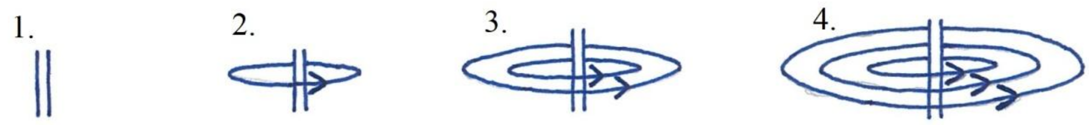
$$S = \pi r^2$$

This is due to the fact that, for example, the magnetic force acting on a current-carrying wire is always directed perpendicular to the direction of both the current and the magnetic field. However, in both cases, it is possible to consider the expression C for the circumference of a circle:

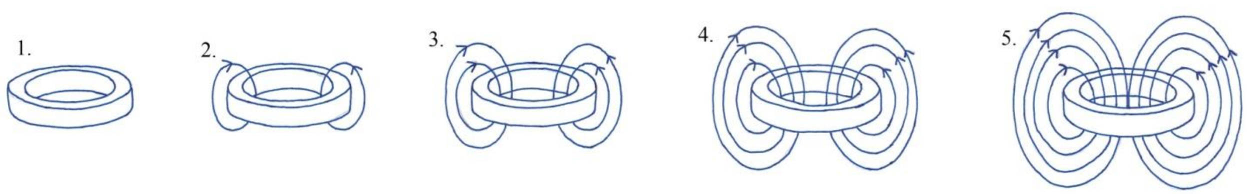
$$C = 2\pi r$$

since the circumference C of a circle appears in the equations for both the area of a sphere and the area S of a circle.

The magnetic field and the electric field are created in space at the speed of light c, which also means that the electric field and the magnetic field change each other in space at the speed of light. For example, the formation of a magnetic field around a moving charge or electric current does not happen instantaneously, but it actually takes time t. The speed of its creation is exactly equal to the speed of light, which is illustrated by the following figure:



In the case of an electric charge starting to move from a standstill, a magnetic field is created at a certain distance from the charge and it takes time. In general, it can be stated that electric and magnetic field changes as well as occurrences/cessations are transferred to the entire surrounding space exactly at the speed of light c. For example, the spatial transmission speed of the creation of a magnetic field is equal to the speed of light, i.e. the magnetic field is created in space at the speed of light. For example, when a ring magnet stops rotating, the field around it changes at the speed of light, not instantaneously. Figure:



In case of the definition of magnetic flux used above:

$$\Phi = BS\ cos\beta$$

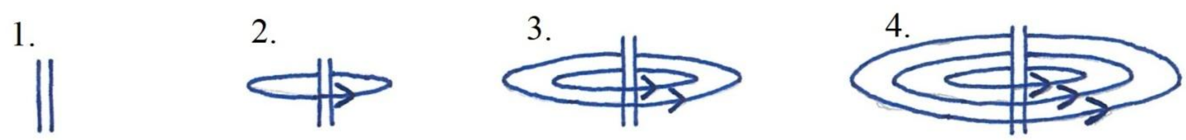
the magnetic field lines must pass through the observed surface. If the observed surface and magnetic field lines are parallel to each other:

$$\Phi = BS\frac{\pi}{2}$$

then according to the equation, magnetic flux does not exist. In this case, there is no angle between the observed surface and the lines of force of the magnetic field, since the observed surface and the lines of force of the magnetic field are parallel to each other. But in this case, we could describe the imaginary surface present when the magnetic field is created:

$$\Phi\frac{2}{\pi} = BS$$

For example, if the electric field changes into a magnetic field, i.e. a magnetic field is created in space, then the lines of force of the magnetic field are created around the electric charge. This means that larger and larger closed lines of force form around the electric charge over time. Figure:



Since the observed surface and the lines of force are parallel to each other, we can treat the observed surface as an imaginary surface of the emerging magnetic field, which increases at the speed of light c over time:

$$\Phi \frac{2}{\pi} = BS = B\pi r^2 = B\pi c^2 t^2$$

From the latter equation, we get the expression for the rate of change of the magnetic flux Φ:

$$\frac{\Phi}{t}\frac{2}{\pi} = B\pi r * c$$

However, it must be noted here that the magnetic flux does not change at the speed of light c, but it contains a quantity that changes at the speed of light. In this case, its value is the circular area S:

$$S = \pi r^2$$

not magnetic induction B, because around the electric charge there are, closed lines of force of the magnetic field increasing in time, which can be considered as an imaginary surface S, which increases in time at the speed of light c:

$$\frac{S}{t} = \frac{\pi r^2}{t} = \pi r * c$$

In this: $c = \frac{r}{t}$ and $r = ct$. It should be noted that such an imaginary surface S is not the surface S present in the definition of magnetic flux:

$$\Phi = BS\ cos\beta$$

but it appears in the expression derived from the equation for the magnetic flux:

$$\frac{\widetilde{\Phi}}{B} = S$$

In the latter, the magnetic flux is present as follows:

$$\widetilde{\Phi} = \Phi \frac{2}{\pi}$$

in which Φ on magnetic flux, but $\widetilde{\Phi}$ is not magnetic flux. In this case, it is not the speed of change of the magnetic field resulting from the definition of change of magnetic flux:

$$\frac{\Phi}{t} = \frac{BScos\beta}{t}$$

but in this case we only dealt with the change in time caused by the field itself

$$\frac{\widetilde{\Phi}}{t} = \frac{BS}{t} = B\frac{S}{t}$$

leaving physical bodies with the standing mass not taken into account here.

Since the field surrounding the charge also changes due to the change of the electric field to a magnetic field, the change of the field starts from the charge and spreads in space away from the charge. The further the change propagates from the charge, the larger the radius r, which is why the area S is also larger:

$$S = \pi r^2$$

Since the change in the field propagates in space exactly at the speed of light c, the area S also "increases" exactly at the speed of light c:

$$S = \pi c^2 t^2$$

Therefore, on its "surface" time (and indeed space) has transformed to infinity:

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

but in the direction of change. This is similar to the infinite transformation of time (and space) that occurs on the Schwarzschild surface at the centre of a black hole's gravitational field. Its size is determined by the equation for the Schwarzschild radius R:

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

The Schwarzschild surface of a black hole is also called a trapped surface in spacetime. The spacetime interval is exactly equal to zero on the Schwarzschild surface of a black hole:

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

It follows from all this that due to the short-term existence of the electromagnetic field surrounding the charge, the charge is also briefly surrounded by a "trapped surface in space-time", which in this case is flat (i.e. circular, not spherical).

2.4 The changing of the field in time and space

The magnetic flux cannot change at the speed of light c, but it includes a quantity that changes at the speed of light. This changing quantity is the surface area S, not the magnetic induction B, because around the electric charge, increasingly larger closed magnetic field lines of force appear in time, which can be considered as an imaginary surface S, which increases in time at the speed of light c. Such an imaginary surface S is not the surface S present in the definition of magnetic flux:

$$\Phi = BS\ cos\beta$$

but it appears in the expression "derived" from the equation for the magnetic flux:

$$\frac{\widetilde{\Phi}}{B} = S$$

In the latter, the magnetic flux occurs as follows:

$$\widetilde{\Phi} = \Phi \frac{2}{\pi}$$

where Φ is a magnetic flux, but $\widetilde{\Phi}$ is not a magnetic flux. In this case, it is not the speed of change of the magnetic field resulting from the definition of change of magnetic flux:

$$\frac{\Phi}{t} = \frac{BScos\beta}{t}$$

but in this case we only dealt with the change in time caused by the field itself

$$\frac{\widetilde{\Phi}}{t} = \frac{BS}{t} = B\frac{S}{t}$$

leaving physical bodies with the standing mass not taken into account here. The magnetic flux Φ indicates the extent to which the magnetic field lines pass through the observed surface due to the size and position of this surface in the magnetic field:

$$\Phi = BScos\beta = B_n S = BS$$

In this case, the surface is perpendicular to the vector B: $cos\beta = 1$.

Faraday's law of induction ε_i and the quantity $\widetilde{\Phi}$ describe the change of the field in time, but the change of the field in space is described by different differential operators. These include, for example, the gradient of the scalar field:

$$gradf = \left(\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}, \frac{\partial f}{\partial z}\right) = \frac{\partial f}{\partial x}\vec{i} + \frac{\partial f}{\partial y}\vec{j} + \frac{\partial f}{\partial z}\vec{k}$$

divergence of a vector field:

$$div\vec{F} = \frac{\partial F_x}{\partial x} + \frac{\partial F_y}{\partial y} + \frac{\partial F_z}{\partial z} = \vec{\nabla}\vec{F}$$

and a vector field rotor:

$$rot\vec{F} = \vec{\nabla} \times \vec{F} = \left(\frac{\partial F_z}{\partial y} - \frac{\partial F_y}{\partial z}, \frac{\partial F_x}{\partial z} - \frac{\partial F_z}{\partial x}, \frac{\partial F_y}{\partial x} - \frac{\partial F_x}{\partial y}\right)$$

The gradient of a scalar field indicates the change of the field in space. The change of the vector field in space is indicated by the divergence, but the divergence primarily indicates the source of the vector field. The rotor shows the vorticity of the vector field (how twisted the field is). In the following, we briefly show the possibility of describing the magnetic flux through the vector field flux and its relations with the differential operators describing the field. For example, from Ampere's law we get the definition of magnetic induction B:

$$B = \frac{F}{Il}$$

in which case the magnetic field is perpendicular to the direction of the current: $sin\alpha = 1$. Therefore, we can express the magnetic induction B in the magnetic flux equation as follows:

$$\Phi = \frac{F}{I}\frac{S}{l}$$

The definition of the vector field flux can be seen from the latter expression:

$$\Phi(Il) = FS$$

or

$$\Phi_F = FS$$

which is similar to the definition of magnetic flux:

$$\Phi = BS$$

The only difference is that for B the flux of the magnetic induction is seen through the surface S, but for F the flux of the vector field is seen through the surface S. We can use the following form:

$$d\vec{s} = \vec{n}ds$$

in which there is a vector of the surface normal: $|\vec{n}| = 1$. According to this, we get the following differential equation:

$$d\Phi_F = \vec{F}d\vec{s} = \vec{F}\vec{n}ds = F_n ds$$

which appears as an integral as follows:

$$\Phi_F = \iint_S \vec{F}d\vec{s} = \iint_S F_n\, ds$$

The member F_n is the normal projection of F_n onto the $\vec{n}$ direction. For a closed surface, the integral can be represented as follows:

$$\Phi_F = \oiint_S \vec{F}d\vec{s}$$

In the latter, the famous Grauss-Ostrogradsky equation can be seen:

$$\oiint_S \vec{F}d\vec{s} = \iiint_V div\vec{F}dV$$

In the case of a triple integral, it is an element of space. Formulas of this kind are called space integrals, but surface integrals are double integrals:

$$\iint \vec{F}d\vec{S}$$

Three components are also used in case of a surface integral:

$$F_x(x, y, z)$$

$$F_y(x, y, z)$$

$$F_z(x, y, z)$$

however, in case of a z coordinate, it is expressed as follows:

$$z = z(x, y)$$

Therefore, we can write:

$$F_x(x, y, z) = F_x(x, y, z(x, y))$$

Since the surface element can be expressed as a differential equation:

$$d\vec{S} = \left(-\frac{\partial z}{\partial x}\vec{\imath} - \frac{\partial z}{\partial y}\vec{\jmath} + \vec{k}\right)dxdy$$

we get as the surface integral:

$$\iint_L \left[F_x\left(-\frac{\partial z}{\partial x}\right) + F_y\left(-\frac{\partial z}{\partial y}\right) + F_z\right]dxdy$$

At this point, the following question may arise: how to obtain the differential equation:

$$d\vec{S} = \left(-\frac{\partial z}{\partial x}\vec{\imath} - \frac{\partial z}{\partial y}\vec{\jmath} + \frac{\partial z}{\partial z}\vec{k}\right)dxdy$$

in which $\frac{\partial z}{\partial z}$ cancels out:

$$d\vec{S} = \left(-\frac{\partial z}{\partial x}\vec{\imath} - \frac{\partial z}{\partial y}\vec{\jmath} + \vec{k}\right)dxdy$$

We will show this briefly as follows. The expression in parentheses contains a nabla, or a vector operator:

$$\vec{\nabla} = \frac{\partial}{\partial x}\vec{\imath} + \frac{\partial}{\partial y}\vec{\jmath} + \frac{\partial}{\partial z}\vec{k} = \left(\frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z}\right)$$

not directly divergence:

$$div\vec{F} = \frac{\partial F_x}{\partial x} + \frac{\partial F_y}{\partial y} + \frac{\partial F_z}{\partial z}$$

or

$$div\vec{F} = \vec{\nabla} * \vec{F} = grad * \vec{F}$$

An operator is a rule by which one function is obtained from another function. The divergence of the vector field shows the source of the vector field, i.e. the change of the vector field in space. Apart from divergence, nabla is also used in the gradient of a scalar field (gradf), which also describes the change of the field in space, not in time. The gradient is directed in the direction of the field growth, whereas the vector field flux is also a scalar quantity. Above we saw that the surface integral is related to the double integral:

$$\iint \vec{F}d\vec{S}$$

It contains three components (x, y, z), in which the third component manifests through the first two: $z = z(x, y)$. If we now take the gradient from the z-coordinate:

$$\vec{\nabla}z = gradz = \frac{\partial z}{\partial x}\vec{\imath} + \frac{\partial z}{\partial y}\vec{\jmath} + \frac{\partial z}{\partial z}\vec{k} = \frac{\partial z}{\partial x}\vec{\imath} + \frac{\partial z}{\partial y}\vec{\jmath} + \vec{k}$$

and we differentiate it in turn through dx and dy, then we get a differential equation:

$$d\vec{S} = \left(\frac{\partial z}{\partial x}\vec{\imath} + \frac{\partial z}{\partial y}\vec{\jmath} + \vec{k}\right)dxdy$$

or

$$d\vec{S} = \left(-\frac{\partial z}{\partial x}\vec{\imath} - \frac{\partial z}{\partial y}\vec{\jmath} + \vec{k}\right)dxdy$$

which is necessary to define the surface integral:

$$\iint_L \left[F_x\left(-\frac{\partial z}{\partial x}\right) + F_y\left(-\frac{\partial z}{\partial y}\right) + F_z\right]dxdy$$

In the vector operator or nabla in parentheses, some terms are represented as negative:

$$-\frac{\partial}{\partial x}\vec{\imath} - \frac{\partial}{\partial y}\vec{\jmath} + \frac{\partial}{\partial z}\vec{k}$$

We briefly show its mathematical derivation as follows. In the vector operator nabla $\vec{\nabla}$:

$$\vec{\nabla} = \frac{\partial}{\partial x}\vec{\imath} + \frac{\partial}{\partial y}\vec{\jmath} + \frac{\partial}{\partial z}\vec{k}$$

we move two members to the other side of the equals sign:

$$\vec{\nabla} - \frac{\partial}{\partial x}\vec{\imath} - \frac{\partial}{\partial y}\vec{\jmath} = \frac{\partial}{\partial z}\vec{k}$$

This results in:

$$-\frac{\partial}{\partial x}\vec{\imath} - \frac{\partial}{\partial y}\vec{\jmath} + \vec{\nabla} = \frac{\partial}{\partial z}\vec{k}$$

If we now manifest nabla $\vec{\nabla}$ in the obtained expression:

$$-\frac{\partial}{\partial x}\vec{\imath} - \frac{\partial}{\partial y}\vec{\jmath} + \frac{\partial}{\partial x}\vec{\imath} + \frac{\partial}{\partial y}\vec{\jmath} + \frac{\partial}{\partial z}\vec{k} = \frac{\partial}{\partial z}\vec{k}$$

then we see that we can finally rewrite the form of the equation as follows:

$$-\frac{\partial}{\partial x}\vec{\imath} - \frac{\partial}{\partial y}\vec{\jmath} + \frac{\partial}{\partial z}\vec{k} = -\frac{\partial}{\partial x}\vec{\imath} - \frac{\partial}{\partial y}\vec{\jmath} + \frac{\partial}{\partial z}\vec{k}$$

or

$$-\frac{\partial}{\partial x}\vec{\imath}-\frac{\partial}{\partial y}\vec{\jmath}+\frac{\partial}{\partial z}\vec{k}$$

In fact, it was also seen beforehand that the equations would also have resulted in such an equation:

$$\frac{\partial}{\partial z}\vec{k}=\frac{\partial}{\partial z}\vec{k}$$

but there is nothing to do with such an equation in the expression for the surface integral.

In the vector operator nabla $\vec{\nabla}$ we have to consider the minus signs because it expresses the direction of the field in space. For example, in the electric field strength equation:

$$\vec{E}_T=-grad\varphi$$

the minus sign also expresses the direction of the field in space. However, if, for example, a homogeneous magnetic field were aimed at the z-axis:

$$\vec{B}=(0,0,B)$$

then the components of this rotor would be expressed as follows:

$$rot_x\vec{A}=\frac{\partial}{\partial y}A_z-\frac{\partial A_y}{\partial z}=0$$

$$rot_y\vec{A}=\frac{\partial}{\partial z}A_x-\frac{\partial A_z}{\partial x}=0$$

$$rot_z\vec{A}=\frac{\partial}{\partial z}A_y-\frac{\partial A_x}{\partial y}=B-0=B$$

Consequently, the vector potentials of a homogeneous magnetic field located along the z-axis are:

$$\vec{A}=(0,B_x,0)$$

$$\vec{A}=(-B_y,0,0)$$

$$\vec{A}=\left(-\frac{B_y}{2},\frac{B_x}{2},0\right)$$

Previously, we saw how the definition of the surface integral "appears" in the expression for the magnetic flux. However, in addition, the "derivation" of the line integral can also be shown. For example, in the abovementioned magnetic flux equation:

$$\Phi=\frac{F}{I}\frac{S}{l}$$

the area S can be expressed as the square of the length: $S=l^2$, which gives us the equation in the following form:

$$\Phi = \frac{Fl}{I}$$

or

$$\Phi(I) = Fl$$

This is the expression for a one-dimensional integral, or line integral, if we present it as a differential equation:

$$W = \int \vec{F}\, d\vec{l} = \int \vec{F}\,(x, y, z) d\vec{l} = \int \vec{F}_L\, dl$$

In this:

$$dl = \sqrt{dx^2 + dy^2 + dz^2}$$

In case of a closed line, the line integral is expressed as follows:

$$W_L = \oint_L \vec{F} d\vec{l}$$

This is also called vector field circulation in physics. If the circulation is nonzero, the field is eddy. If S is a smooth surface the path line of which is the curve L and $\vec{F}$ is differentiable on the surface S, then we get the Stokes theorem used widely in physics:

$$\oint_L \vec{F} d\vec{l} = \oiint_S rot\vec{F}\, d\vec{S}$$

A vector field $\vec{F}$ is called potential in region D if $rot\vec{F} = 0$ at each of its points. However, a vector field $\vec{F}$ is called solenoidal if $div\vec{F} = 0$ at every point of this region D. In this case, it is a free field of the source.

2.5 The surface of a black hole and the rate of change of the electromagnetic field

Let us assume that we have a annulus, which rotates at the speed of light c. Due to the contraction of length:

$$dl = \sqrt{1 - \frac{v^2}{c^2}} dl_0 = \sqrt{1 - \frac{v^2}{c^2}} r_0 d\varphi$$

the length l of an “edge line” measurable by an observer is equal to zero, compared to the length l_0 of an “edge line” of a stationary annulus. The angular speed of an annulus is ω, the linear velocity of extreme points of an annulus is

$$v = r\omega$$

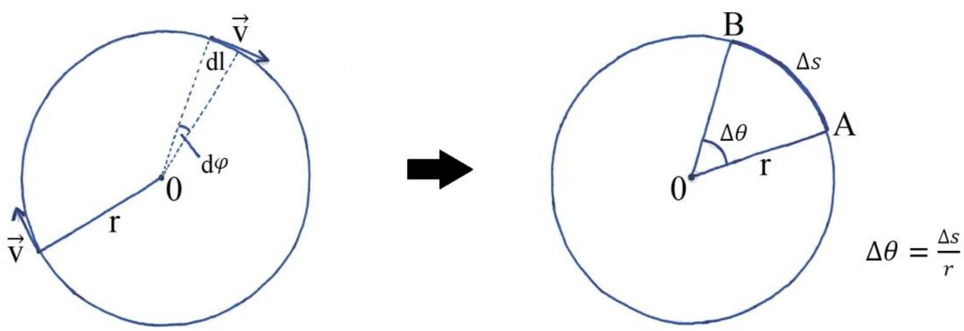
and l is the length of an edge line of an annulus. Since the effect of shortening of lengths does not occur perpendicular to the direction of movement, the radius of an annulus does not change compared to the stationary one:

$$r = r_0$$

In case of a stationary annulus dl_0 describes the length of segments and c is the speed of light in vacuum. If we integrate the expression for dl over the whole circumference, it will give us the equation for the length of the circle:

$$l = \int_0^{2\pi} \sqrt{1 - \frac{v^2}{c^2}} r_0 \, d\varphi = 2\pi r_0 \sqrt{1 - \frac{v^2}{c^2}} = l_0 \sqrt{1 - \frac{v^2}{c^2}}$$

which is actually the equation for contraction of lengths in the theory of special relativity. The figure concerning the rotation of an annulus:



Since an annulus can not actually rotate at the speed of light c, we will use “the principle of speed of change in fields” instead of it. We will explain this in greater detail in the following.

Newton’s II law is, in its most general form, expressed as a differential equation:

$$\vec{F} = \frac{d\vec{p}}{dt}$$

This is the law of change of linear momentum or impulse. In classical mechanics, the relation between impulse p and speed v is linear, but in the special theory of relativity, it is no longer the case. In the theory of relativity, “the principle of relativity” applies, which says that the force F must be invariant or equal in all inertial systems. Therefore, we can write impulse p in the following form:

$$\vec{p} = \frac{m\vec{v}}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{m\vec{v}}{\sqrt{1 - \beta^2}} = my\vec{v}$$

in which $\vec{\beta} = \frac{\vec{v}}{c}$ and $y = \frac{1}{\sqrt{1-\beta^2}}$. Acceleration a is expressed as a quotient of speed v and time t:

$$\vec{a} = \frac{d\vec{v}}{dt}$$

In the light of all foregoing considerations, we can write Newton’s II law in a relativistic form:

$$my\vec{a} + my^3(\vec{\beta}\vec{a})\vec{\beta} = \vec{F}$$

in which $(\vec{\beta}\vec{a})$ indicates the dot product of vectors $\vec{\beta}$ ja $\vec{a}$.

At this point it must be noted that in case of low speeds $\vec{\beta} \to 0$ and $y \to 1$, we get from the relativistic equation for Newton's II law the classical equation:

$$\vec{F} = m\vec{a}$$

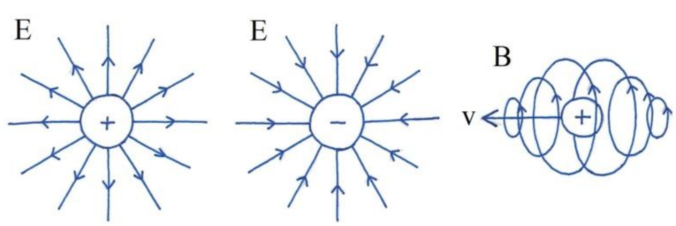
Such a result convincingly shows that in case of small speeds (compared to the speed of light in vacuum), classical mechanics appears to be a special case of relativistic mechanics. At high speeds, force and acceleration are no longer proportional. If the vectors of speed and force are "confluent", the relativistic equation for Newton's II law can be written in the following form:

$$mya(1 + y^2\beta^2) = F$$

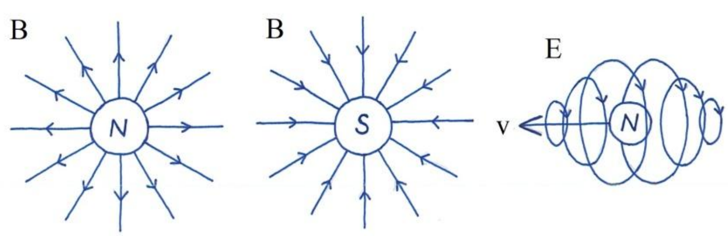
From the latter, it can be seen that at high speeds acceleration starts to depend on, in addition to force F, the speed of a body v as well. As a consequence, in order to give the same acceleration at high speeds, much more force must be applied than in case of low speeds. This means that the force that creates acceleration starts to increase unrestrictedly when approaching the speed of light. As a consequence, a body (that has an inertial mass) can not achieve the speed of light.

Not one body can achieve the speed of light c, however, fields themselves are created and changed at the speed of light c. For example, creation of a field in the surrounding space required certain time. This means that in case of changing of the source of the field (for example an electric charge), the field at a certain distance from the charge also changes and it takes time. The changes in the field are transferred to the whole surrounding space at the speed of light c, which means that the spatial speed of transfer of the change in the field is equal to the speed of light c. The field as well as the change in the field propagates in space at the speed of light c. From this, it follows that the speed of propagation of the impulse of an electric field coincides with the speed of light c.

Magnetic field B is created around a moving electric charge, the figure:



An electric charge E is created around a moving magnetic pole, the figure:



Creation of a magnetic field in space surrounding an electric charge requires time. For example, in case of an electric charge that is beginning to move, magnetic field is created at a certain distance from the charge and it requires time. Any changes in energy field as well as creation/cease are transferred to the whole surrounding space at the speed of light c, which also means that the speed of spatial transfer of creation of a magnetic field is equal to the speed of light or magnetic field is created in space at the speed of light c. From this, it follows that the speed of propagation of an impulse of a magnetic field also coincides with the speed of light c.

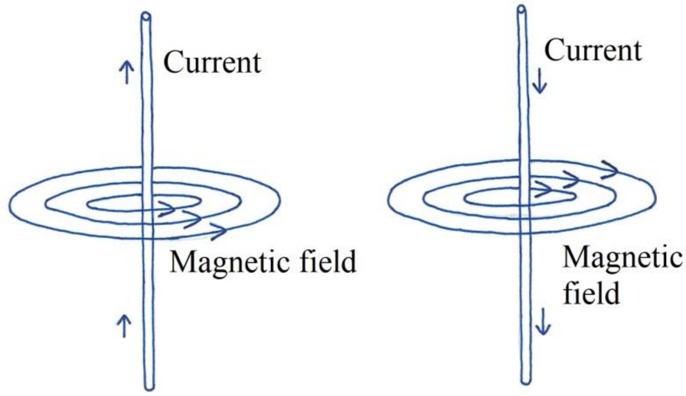


Figure: Magnetic field lines around a straight live wire

An immobile observer registers the electric field of an immobile charge, but a moving charge creates a magnetic field for an immobile observer as well. A live wire is surrounded by magnetic field as well, since as a result of moving charge carriers, a magnetic field is created. Changing electric field also creates a magnetic field. Magnetic field is a vortex field, since magnetic field lines are closed or they have neither a beginning nor an end.

All parts of a circuit create a magnetic field at the centre of the annulus, which is directed along the axis of the circuit. The resultant field is the strongest on the axis of the circuit at the centre of the circuit. The magnetic field lines of a circuit are closed curves.

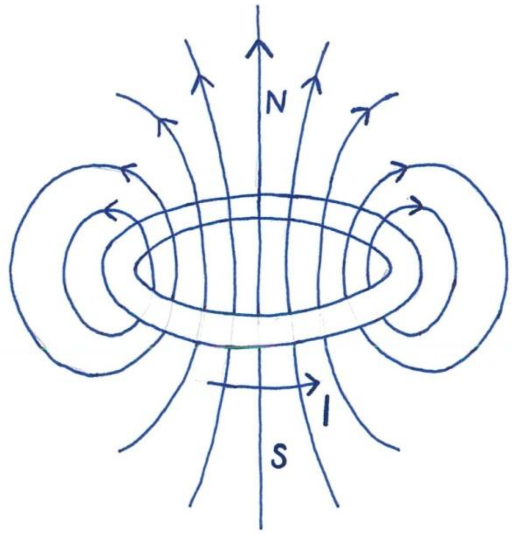
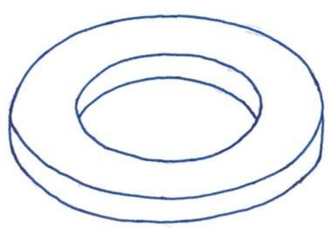


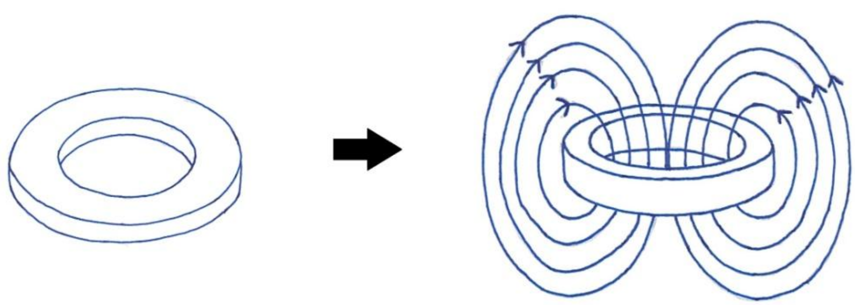
Figure: Magnetic field lines around a live ring wire.

Subsequently, we present the principal outline or principal model for creating a tunnel in spacetime, which we can call “the physical system for creating a tunnel in spacetime”:

1. Let us assume that we have a “metal annulus” which is electrically charged (positively or negatively). The annulus does not move or rotate in space and it is not live as well. In this case, only an electric force is surrounding the metal annulus. Figure:



2. However, if the metal annulus starts to rotate around its imaginary axis, then, as a result of moving charge carriers or in case of creation of electric current, a magnetic field is also created around the metal annulus. A changing electric field creates a magnetic field as well. Figure:



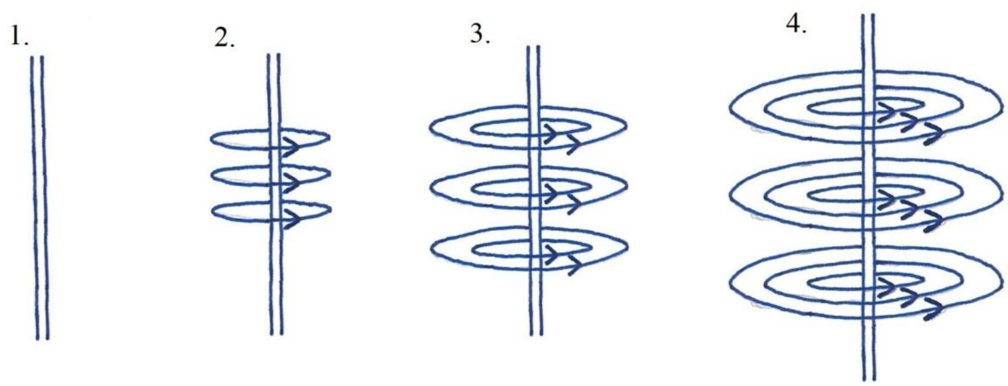
Magnetic field is an ambient electric field (i.e. it moves in space). The propagation of a changing electric field is mediated by magnetic field. For example, the change of an electric field in one point in space firstly creates a changing magnetic field and the change in this magnetic field brings about (through electromagnetic induction) the change in an electric field in a neighbouring point. This means that any change in electric or magnetic field propagates in space as waves. This created wave is indeed an electromagnetic wave or, therefore, an electromagnetic field.

> According to this conception, in case of a change in an electric field of a metal annulus, a “brief” “circular” electromagnetic wave or electromagnetic field surrounding the annulus is created, which leaves the charged annulus or kind of “expands” away from the annulus and which can, according to the preceding analysis, be also interpreted as a probability wave of a photon or probability field, on which’s “surface” time and space have transformed to infinity.

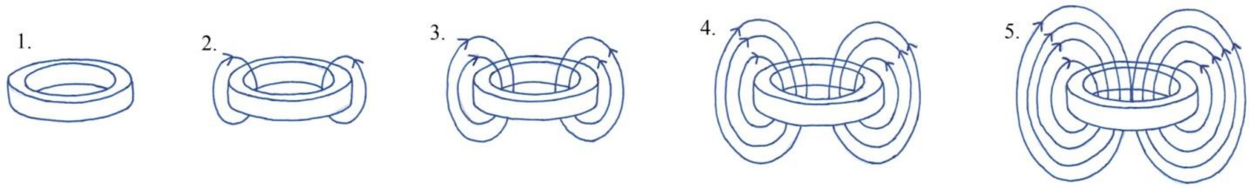
3. Since in case the metal annulus rotates around its imaginary axis, all the points of the annulus move simultaneously, then in this case a magnetic field is created simultaneously everywhere around the metal annulus. This is a very important condition.

> Magnetic field must be created around the metal annulus everywhere at once, not so that a magnetic field is creates firstly on one end of the annulus and a little bit later on the other end. Therefore, the annulus must rotate. This is a very important condition.

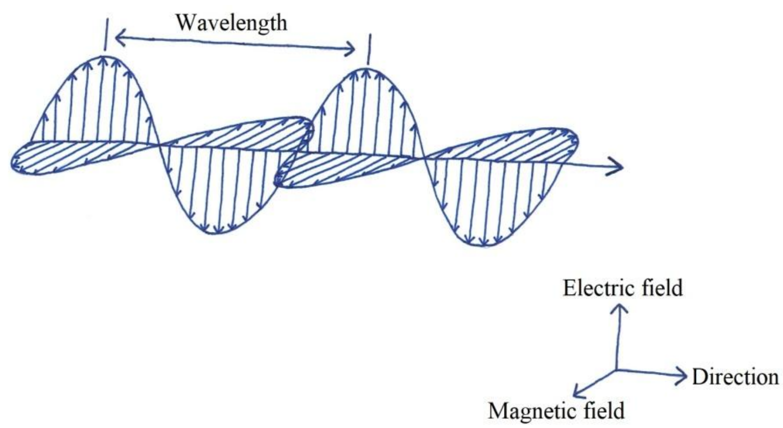
4. Magnetic field is created in space at the speed of light c or electric field is transformed into magnetic field in space at the speed of light c. Figure:



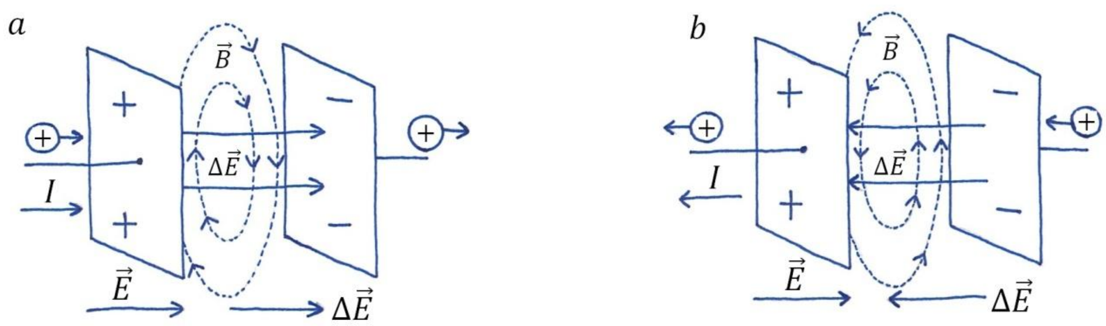
The creation of a magnetic field in space surrounding the metal annulus takes time. In case of an electric charge that is starting to move, magnetic field is created at a certain distance from the charge and it takes time. Changes in electric field and magnetic field and their creation/cease are transferred to the whole surrounding space at the speed of light c, which means that, for example, the speed of spatial transfer of creation of a magnetic field is equal to the speed of light c or magnetic field is created in space at the speed of light c. Figure:



For example, an electromagnetic wave is propagation of an electric field and a magnetic field changing each other in space. A changing electric field creates a magnetic field and a change in magnetic field in turn creates an electric field. Such an electric and magnetic fields turning into each other happens at the speed of light c and the speed of propagation of electromagnetic wave in vacuum is also the speed of light c. An electromagnetic wave can also be seen as a movement of a photon of a quantum particle in space, which's inertial mass m is zero and energy E can be expressed as an equation for the well-known Max Planck's quantum energy E. Figure:



Between capacitor plates, the passage of alternating current also occurs also in case of empty space by means of a changing electric field. For example, displacement current is a phenomenon, which's occurrence is accompanied by the charge carriers starting to move on the other plate due to the strengthening electric field of the charging plate. Movement of charges is accompanied by a magnetic field, however, it also exists in case of absence of charge carriers in an empty space between the capacitor plates. If the magnetic field changes, an electric vortex field is created independently of the origin of the change. For example if the current changes in the coil or if a permanent magnet is shifted. If an electric field changes, a magnetic field is also created independently of the origin of the changing electric field. This also means that propagation of a changing electric field is mediated by a magnetic field. Between capacitor plates, a magnetic field exists in case of passage of an alternating current, which's field lines surround the direction of change of an electric field. Magnetic field lines are closed lines or vortexes and the change in electric field propagates in space exactly at the speed of light c: Figure:



5. Since magnetic field is created in space at the speed of light c, this energy field kind of "moves" away from the metal annulus at the speed of light c. By "movement" of an energy field, it is understood that space surrounding a metal annulus is filled with an energy field (i.e. magnetic field) in time, which "originates" from the surface of the metal annulus. Therefore, on this "surface", time (as well as space) have transformed to infinity:

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

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:

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

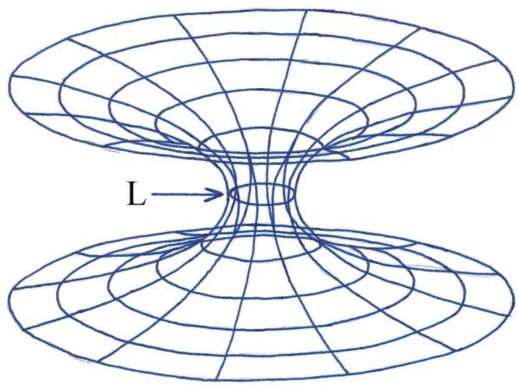
time t' would "transform" or "slow down" to infinity:

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

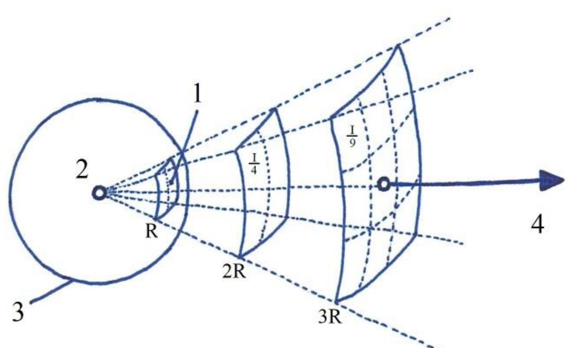
Time (and space) have transformed or bent to infinity also on the Schwarzschild surface at gravitational centre of a black hole, the size of which is determined by the equation for the Schwarzschild radius R:

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

The Schwarzschild radius R of a black hole determines the size of Schwarzschild surface S, circumference of which is L. From this, it follows that if a magnetic field is created around a metal annulus, the annulus is also briefly surrounded by a “trapped surface in spacetime”, which can, according to the forementioned analysis, be interpreted as a hole in spacetime, which in turn is the entrance or exit of a tunnel in spacetime or wormhole. The figure:



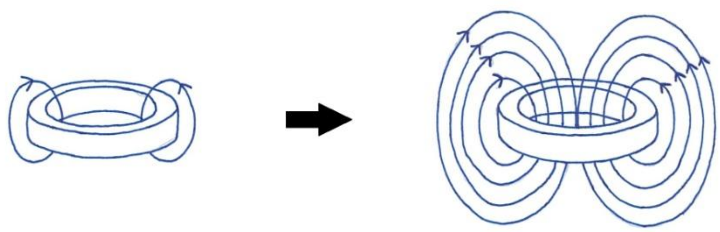
In case of change of any energy field, a brief “trapped surface in spacetime” also appears, on which time and space have transformed or bent to infinity according to the theory of special relativity. Such a statement requires further explanation. For example, if a magnetic field is generated in empty space at the speed of light c, then the temporary “borderline” between empty space and an energy field can notionally be interpreted as a two-dimensional “surface” on which time and space have transformed to infinity, because it “moves” (“propagates”) in space at the speed of light c. The figure (exemplified by a charged sphere):



1. Intensity: $I = \frac{W_{EM}}{S}$
2. Source power: W_{EM}

3. Imaginary sphere area: $S = 4\pi R_0,\ R_0 = R, 2R, 3R \ldots$
4. Direction of propagation of EM wave

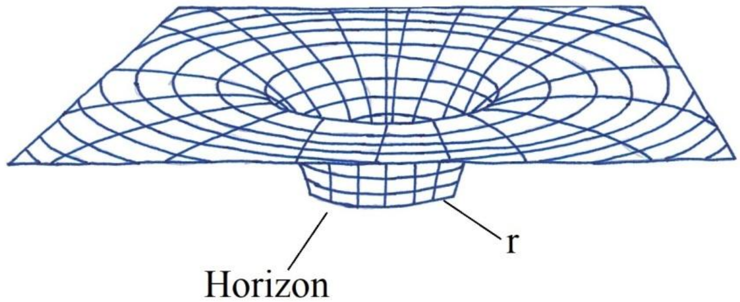
This means that this surface increases in time at the speed of light c. At this point, it must be noted that how far can be moved in time depends on the size of the surface area of this surface. In that case, only the size of surface area of such a surface is taken into account, which also equals to the size of the outer surface area of a physical body (in this case an annulus), which means that it equals to the size of the surface area of the creator of the field itself. For example, in case of an electrically charged human being, the size of the surface area of a human body would be considered. In this case, the size of the smallest surface area of an surface increasing in time would be taken into account. Figure:



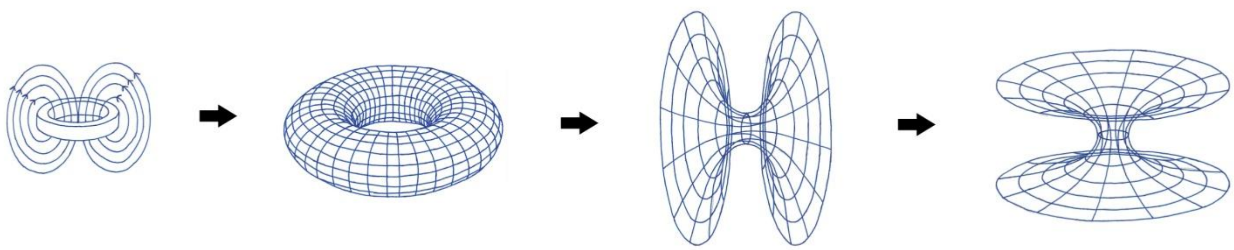
At this point, the question arises, why must the size of the smallest surface area be taken into account in the calculations? The answer to this question is actually very simple. Since the surface area increases over time at the speed of light c, the transformations of time and space can have their effect even before the increasing surface can become very large. On the surface, time and space have transformed/curved to infinity just like on the Schwarzschild surface of a black hole. Since the smaller surface area exists earlier in time than the larger area, it is therefore the size of the smaller area that must be taken into account. The smallest surface area is equal to the outer surface area of the field generator itself, which in this case is the entire outer surface area of the annulus.

In fact, they are not completely equal, because the resulting trapped surface in space-time is slightly larger than the entire outer surface area of the annulus. However, such a difference is so small that it can in principal be ignored in the calculations.

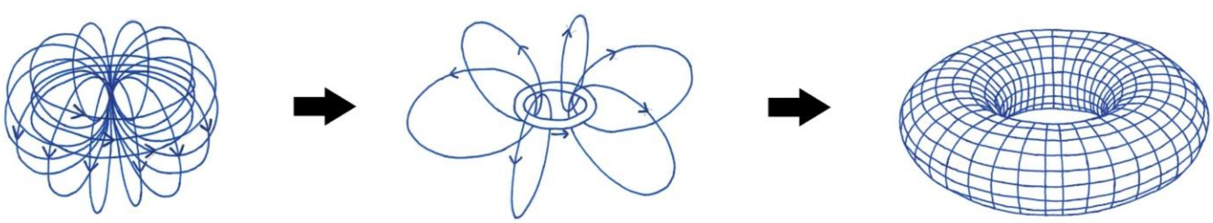
On the Schwarzschild surface at the centre of the black hole, or the "horizon" of the black hole, time and space have also transformed or bent to infinity. The Schwarzschild radius r of the black hole determines the size of the Schwarzschild surface S. Figure:



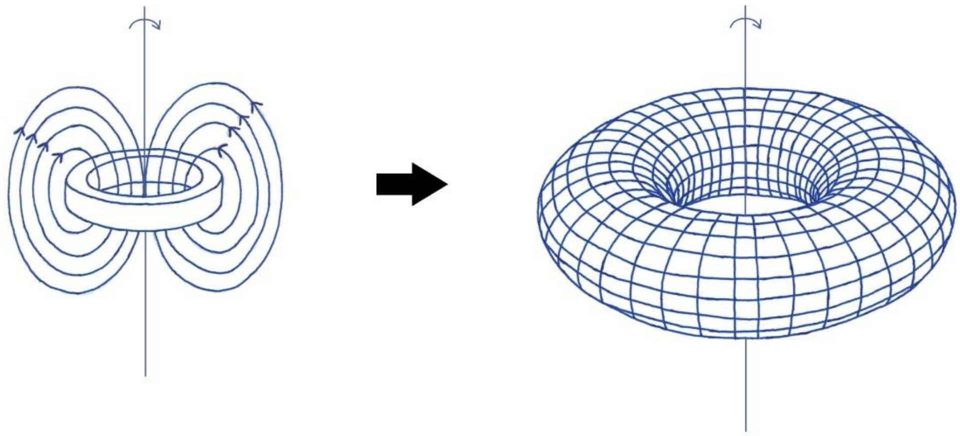
6. In case of creation of a magnetic field around the metal annulus, the annulus is also briefly surrounded by a "trapped surface in spacetime", which, based on the above analysis, can also be interpreted as a hole in spacetime, which in turn is the entrance and exit of a tunnel in spacetime or wormhole. The trapped surface in spacetime (a tunnel in spacetime) is thus in this case shaped like a metal annulus, which resembles a doughnut. Figure:



The magnetic field surrounding the metal annulus is also geometrically similar to the shape of the trapped surface in spacetime, which resembles a doughnut. This means that the closed field lines of the magnetic field form a doughnut-shaped energy field around the metal annulus, which also determines the geometric shape of the trapped surface in spacetime. The figure:



7. A magnetic field is a changing (i.e. moving in space) electric field. The magnetic field is created as a result of the movement of charge carriers in space. Since in this case, the creation of a magnetic field, i.e., the creation of an electric field moving in space, is also accompanied by the creation of a trapped surface in spacetime, the resulting trapped surface in spacetime (i.e. tunnel in spacetime) should also move in space, or in this case "rotate" in the same direction as the metal annulus. But the "rotation angle" of the donut-shaped trapped surface in spacetime (tunnel in spacetime) is extremely small (almost non-existent, but still greater than the Planck length), because the time period of the existence of the tunnel in spacetime is simply very small. Figure:



8. Another possibility would be that an electric current is passed through the metal annulus and only then (during the electric current) does the annulus start to rotate in space or move. This would result in a changing magnetic field around the annulus. In this case, a magnetic field caused by the electric current occurs at first, and after that a changing magnetic field caused by the rotation of the annulus. A change in the magnetic field creates an electric (vortex) field and the rate of change is equal to the speed of light in vacuum.

    For example, if a permanent magnet would move relative to an observer, the magnetic field would change at the observer's location and the observer would register the presence of an electric field. A change in the magnetic field creates an electric field.

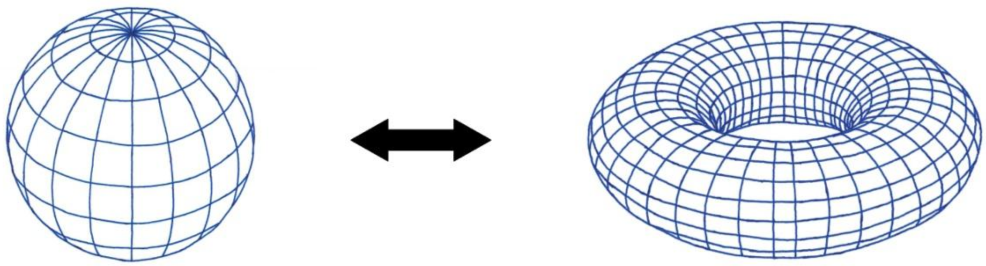
At this point, it is worth noting that one does not need to have an extremely large mass M or energy E to create a human-sized Schwarzschild surface:

$$t` = \frac{t}{\sqrt{1-\frac{2GM}{c^2r}}} = \frac{t}{\sqrt{1-\frac{R}{R}}} = \infty$$

which actually is not possible. In order to create a human-sized Schwarzschild surface, the speed of change of an energy field c is enough:

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

which can already be created artificially, whereby independently of the shape of the trapped surface in spacetime. The figure:



In this case, the energy/mass size of the field is not important. This means that the generator of the Schwarzschild surface is only the rate of change or creation of the electromagnetic field c, in which case the size of energy/mass of the same field is no longer important.

In order to bend spacetime, a very large electric charge is actually needed, but the electric charge of the body cannot be indefinitely large, because then repulsive forces will appear between the charges, which would prevent bending of spacetime. Likewise, the electrical capacity of the body does not allow it to have indefinitely large charge. For example, on a capacitor, i.e. in the space between two surfaces charged with unlike charge, 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 the capacitance of a capacitor is 0.6 mF and its charge is 0.12 C, then the capacitor "only" has energy of 12 J.

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 strong 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 last formula, we get the body charge q to be 1.16 * 10^{17} coulombs, or C, if the radius r is 1 meter and the dielectric permittivity ε is approximately 1. This amount of energy, or in this case electric charge q

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

in which

$$E = 6{,}0500 * 10^{43}\ \approx 10^{44}\ J$$

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

The size (radius R) of the body carrying the electric charge calculated in this way (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 repulsive forces between the charges would start to act.

One of the largest electric field strengths that can exist in free nature is found in the hydrogen atom. For example, at the location of an electron in a hydrogen atom, the field strength is $E_T = 5 * 10^{11}\ N/C$. It would be such a field strength that the length of the lightning channel in dry air would be 166 kilometres:

$$\mathrm{l} = \frac{5 * 10^{11}}{3 * 10^{6}} = 166{,}666\ km$$

because when a spark occurs in dry air, the field strength is $3 * 10^{6}\ N/C$. Units can be N/C or V/m.

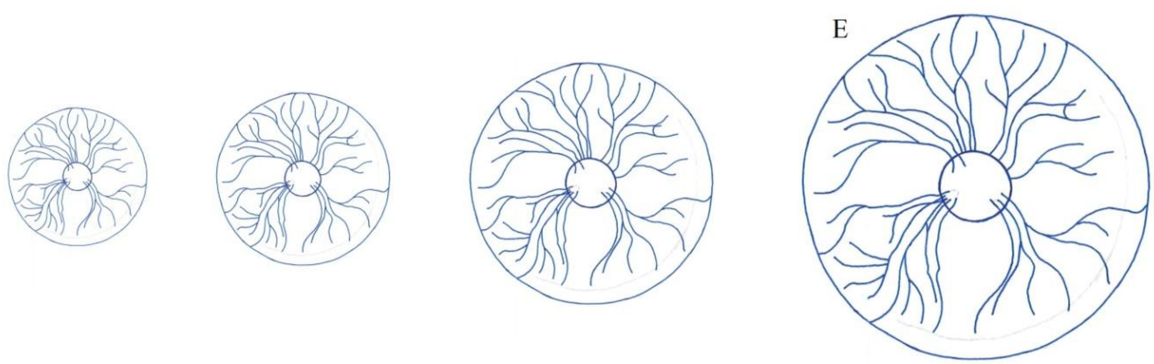
The total world energy production/use of the whole world in 2019 was 158 800 TWh or 158 800 000 000 000 kWh. Because a kilowatt-hour is a multiple of a watt-second in physics (4):

$$1\ kWh = 1000\ watts * 60\ seconds * 60\ minutes = 3{,}6 * 10^{6}\ watt\ seconds\ or\ \ joule$$

then, therefore, we get express the size of such an energy in joules:

$$E = 5{,}7168 * 10^{20}\ J$$

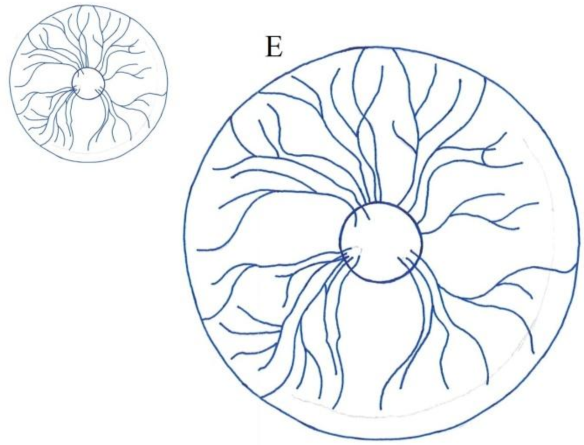
Figure:



However, between 1800 – 2019, the energy production/usage of the whole world was approximately 7 800 000 TWh or 7 800 000 000 000 000 kWh, which is in joules (4):

$$E = 2{,}808 * 10^{22}\ J$$

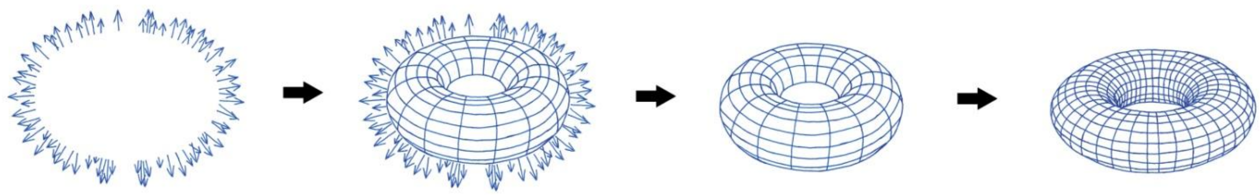
Figure:



> Such amounts of energy are not enough to create a proper wormhole, because to create a human-sized tunnel in spacetime, you need energy in the order of magnitude of $10^{44}\,J$, which cannot be taken or produced anywhere.

If the ring rotates at the speed of light c, then due to the length contraction, the length l of the "edge line" measured by an observer is equal to zero, in addition to the length l_0 of the edge line of a stationary ring. Since in the direction perpendicular to the direction of movement contraction of distances does not exist, the radius of the ring does not change in relation to the stationary one. For a stationary ring, dl_0 describes the length of the segment and c is the speed of light in vacuum. If we integrate the dl expression over the entire circle, it gives us the length contraction equation known from the theory of special relativity. Since the ring cannot actually rotate at the speed of light c, the speed of change of the fields is used instead. In case of any change in the energy field, a "trapped surface in spacetime" also appears for a short time, on which time and space have been transformed, i.e. curved, to infinity according to the theory of special relativity. It follows from the fact that the field changes exactly at the speed of light c. For example, in case of a magnetic field being created around a metal ring, the ring is, for a short time, also surrounded by a “trapped surface in spacetime”, which, based on the above analysis, can also be interpreted as a hole in spacetime, which in turn is the entrance and exit of a tunnel in spacetime or wormhole. In this case, the energy field itself does not contract to zero, but the change of the energy field at the speed of light c is accompanied by a short-term existence of a trapped surface in spacetime. For example, an electromagnetic wave propagating in vacuum can be five meters long, that is, for the electromagnetic wave itself, space has contracted to zero.

Above, we stated that if, when a metal annulus rotates around its imaginary axis, all points of the annulus move at once, then in this case the magnetic field is created everywhere around the metal annulus at once. The magnetic field must be created around the metal annulus everywhere at the same time, not so that the magnetic field is created at one end of the annulus earlier and a little later at the other end of the annulus. That is why the ring must rotate. Such a very, very specific condition is justified by the fact that the physical body must be surrounded or covered by a "closed" surface in spacetime, because then the body is no longer in "contact" or interaction with the surrounding spacetime and absolutely everything else that exists in time and space. Therefore, it can be said that the body exists in hyperspace, i.e. outside spacetime, "where" time and space no longer exist. Figure:



The trapped surface in spacetime is the "boundary" of time and space, where the spacetime we experience on a daily basis ends (that is, ceases to exist). The trapped surface in spacetime can be open or closed. The trapped surface in spacetime is, for example, the surface of a hole in spacetime.

The trapped surface in spacetime can only be open or closed. For example, the surface of a sphere is a closed surface, because the body inside it is completely covered by the spherical surface. But an open surface can be, for example, a circle, a square or a rectangle, because these are two-dimensional surfaces in three-dimensional space that do not allow covering the entire surface of another body.

The trapped surface in spacetime can be geometrically either closed or open. A closed surface is, for example, the surface of a sphere, in which case the body inside the sphere is completely covered by the surface of the sphere. In the case of a closed trapped surface in spacetime, a person travels in time, because it covers the entire surface of the person's body. But, on the other hand, an open surface does not cover the entire surface of some other body. An open surface can be, for example, a circle, square or rectangle. In the case of an open surface, the body does not travel in time, because it does not cover the entire surface of the body, and as a result, the body does not enter hyperspace, i.e. it maintains "contact" with the surrounding spacetime. An open surface can partially cover the surface area of some other body. This means that in the case of a closed surface, the coverage is complete (or 100%), but in the case of an open surface, the coverage is only partial (no longer 100%).

If a person is covered by a closed trapped surface, then, in principal, the person exists in a hole in spacetime, through which the person enters hyperspace. In hyperspace, a person moves through time.

It is also possible to "derive" another way of interpretation from the closed trapped surface in spacetime, which consists of the following. For example, if the emerging trapped surface in spacetime is open and some kind of physical body passes through such a trapped surface in spacetime (similar to passing through the stargate seen in science fiction movies), then you get into another time and space dimensions. In this case, the trapped surface in spacetime (which is open) is like a gate or a window through which one enters another time and space from both sides. If a closed trapped surface in spacetime (for example, in the case of a sphere) is interpreted in physics as the entrances and exits of tunnels in spacetime, then an open trapped surface can be interpreted as a gate or window, through which one enters another time and space from both sides. A good example of this can be an electric field, in which case the resulting open trapped surface in spacetime "cuts" the field lines of the electric field that existed before it. In this case, the field lines of the electric field pass through the trapped surface in spacetime. Visually, it is similar to the situation where a metal plate is placed in a homogeneous electric field, the field lines of the electric field pass through the surface area of the metal plate, i.e. the metal plate cuts the field lines of the electric field. The metal plate has some thickness and it is perpendicular to the electric field.

2.6 Classification of electromagnetic waves

An electromagnetic wave propagates in vacuum exactly at the speed of light c. In matter, its speed may be lower. In an electromagnetic wave, electric and magnetic fields change into each other. The electric field turns into a magnetic field, i.e. the electric field ceases to exist and the magnetic field is also created at the speed of light c. This is shown, for example, by the term $\frac{1}{c}$ in Maxwell's equations:

$$rot\ E = -\frac{1}{c}\frac{\partial H}{\partial t}$$

The speed of propagation of electromagnetic waves can be represented through wavelength λ and time period T:

$$c = \frac{\lambda}{T}$$

where λ is the wavelength and T is the time period. The period T of a light wave can be about 10^{-14} seconds, which is related to the speed of propagation of a light wave in vacuum, not the rate at which the electric and magnetic fields transform into each other. The wave period T indicates the time it takes for a light wave to travel one wavelength λ. This means that the wave travels a distance λ during one oscillation period T. Consequently, the time period T represents the time of existence of one wave.

The emergence of electromagnetic waves in the spacetime of the universe is closely related to electric charges. Magnetic charges do not occur in nature. Therefore, for the sake of simplicity, the electromagnetic waves generated in nature can be classified into two large groups:

1. Due to the movement of an electric charge or a change in the strength of an electric charge, a change in the field occurs, in which case the change in the field propagates in time and space as an electromagnetic wave. The speed of propagation of any field change in spacetime is exactly equal to the speed of light c. The electromagnetic waves caused by the change in the field are directly related to the electric charges that create them.

   For example, electromagnetic waves are "created" in the human brain as a result of the depolarization and repolarization of the nerve fiber (at the locations of the electrical impulses), but unfortunately they do not spread beyond the brain. This means that the human brain does not "radiate" electromagnetic waves into the surrounding space (i.e. ordinary space), as, for example, the antenna of a radio transmitter does.

2. Electromagnetic waves can also propagate in vacuum, which is no longer directly connected to the electric charges that generate them. Electromagnetic waves propagating in empty space are, for example, starlight in outer space.

An electromagnetic wave can be considered as light, since light is also an electromagnetic wave, i.e. the propagation of the mutual transformation of the electric field and the magnetic field in space. However, not every electromagnetic wave is light, or a wave of light. The entire wavelength scale of electromagnetic waves is between about 10^{-12} – 10^{4} meters, but visible light only covers 380 - 760 nanometers of that. Any electromagnetic wave can be called light only "conditionally", since any electromagnetic wave is still a "photon", which is understood in quantum physics as a "particle of light". According to quantum mechanics, any electromagnetic wave is a particle called a photon that has frequency and mass. A photon has no inertial mass.

Electromagnetic waves propagating in vacuum can only be generated artificially. For example, the "excitation" of atomic nuclei, i.e., the occurrence of resonance of atomic nuclei, causes the generation of an electromagnetic wave that propagates in space. For example, body fluids and the nucleus of the hydrogen atom (which is found in many molecules) are very good resonators. Atomic nuclei have angular momentum, or spin, because they rotate. Therefore, protons (protons in atomic nuclei have a positive charge, but neutrons are uncharged) create a magnetic field, both poles of which are located on the axis of rotation of the atomic nucleus. However, it is possible to influence these axis of rotation with the help of an applied magnetic field in the same way as it is possible to direct, for example, a compass needle. Therefore, resonance of atomic nuclei can occur.

Previously, we saw that the electromagnetic waves generated in nature can be classified into two large groups for the sake of simplicity. However, at this point it should also be noted that from each group we can get electromagnetic waves of the other group. Oscillators, also called pendulum-like oscillating electrical systems, are used for this purpose, the oscillation frequency of which is determined by the characteristics of the system. In short, an oscillator is a circuit containing an inductor and a capacitor. A closed oscillator is required to generate electromagnetic oscillation in a limited area of space. However, in order to obtain an oscillation that propagates as a wave in space, an open oscillating circuit must be used, in which case the electromagnetic field no longer remains inside the elements of the oscillator. This is how electromagnetic waves that can propagate in vacuum are generated artificially.

> For example, two metal rods (a Hertzian vibrator or a dipole antenna consisting of two rods) also act as an open oscillator. If these two metal rods are charged oppositely to the breakdown voltage, a spark discharge (i.e. electric current) occurs in the gap between the rods. The rods act as capacitor plates. The electric field existing between the rods changed abruptly in case of occurrence of an electric current. This induces an electromagnetic wave that propagates in space. The generated electromagnetic wave can be registered with another pair of rods, between which a spark is then created. The resulting spark discharge testifies to the arrival of the electromagnetic wave.

General electrical engineering shows us quite convincingly that from one group of electromagnetic waves described above we can get another group of electromagnetic waves. This shows that all electromagnetic waves in the universe are actually exactly the same in their physical nature. For example, an electromagnetic wave propagating in vacuum is actually exactly the same wave as an electromagnetic wave caused by changing fields.

For example, electromagnetic waves can be associated with electric charges, specifically with changing fields caused by the movement of electric charges or changes in their magnitudes. For example, if an electric charge starts to propagate in space or if the strength of an electric charge should change, the electric field surrounding the charge will also change. The changing of the field in space takes some time. This means that the speed of spatial transfer of the field change is exactly equal to the speed of light c. The field and the change in the field propagate in space at speed c, i.e. it takes a certain amount of time for the field to change at a certain distance from the charge when the source of the field changes (in case of movement of an electric charge in space or in case of a change in the strength of an electric charge). For example, the speed of propagation of an electric field pulse matches the speed of light c, i.e. changes in the field are transmitted to the entire surrounding space exactly at the speed of light c.

The propagation of a changing electric field is carried out by means of the magnetic field. For example, a change in the electric field at one point firstly causes a changing magnetic field, and a change in that magnetic field causes (by electromagnetic induction) a change in the electric field at a neighbouring point. This means that any change in the electric or magnetic field propagates through space as a wave. This resulting wave is an electromagnetic wave, i.e. an electromagnetic field. In turn, it follows that when the field of an electric charge changes, the charge is, for a "short time", surrounded by an electromagnetic wave or an electromagnetic field, which moves away from the charge, or kind of "expands" away from the charge, and which can also be interpreted as a photon probability wave, or probability field, according to quantum mechanics.

When the magnetic field changes, an eddy electric field is generated independently of the origin of the change. For example, in case the current in the coil changes or when the permanent magnet is shifted. In case of changes in an electric field, the magnetic field is also created independently of the origin of the changing electric field. This also means that the propagation of the changing electric field takes place via the magnetic field.

2.6.1 Mathematical analysis

All electromagnetic waves in the universe are actually exactly the same in their physical nature. For example, an electromagnetic wave propagating in vacuum is actually exactly the same wave as an electromagnetic wave caused by changing fields. This means that from one group of electromagnetic waves we can get another group of electromagnetic waves. We will show this in the following through mathematical analysis.

A centrally symmetric electric field is described by the electric field strength equation:

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r^2}$$

Since the field is centrally symmetric in this case,

$$E = \frac{q_1}{\varepsilon_0 S}$$

the equation for the surface of a sphere therefore occurs in the given equation:

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

If charge q_1 changes into charge q_2:

$$E = \frac{q_2}{\varepsilon_0 S}$$

in which case:

$$q_1 < q_2$$

then the electric field surrounding the charge must also change. In this case, the strength of the electric field becomes stronger.

Since the field surrounding the charge also changes due to the change in charge, a change in the field starts from the charge and spreads away from the charge in space. The further the change propagates from the charge, the larger the radius r, which is why the area S is also larger:

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

Since the field change propagates in space exactly at the speed of light c, the area S also "increases" exactly at the speed of light c:

$$S = 4\pi c^2 t^2$$

Mathematically, it is also equal to dividing both sides of the equation for surface area:

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

by time t:

$$\frac{S}{t} = \frac{4\pi r^2}{t} = 4\pi r\frac{r}{t} = 4\pi r * c$$

then it can be seen from it that the result:

$$S = 4\pi r * ct$$

coincides with the initial equation: $S = 4\pi r^2$.

The strength of an electric field

$$E_T = k\frac{q}{r^2}$$

is related to the electric force F as follows:

$$E_T q = k\frac{q^2}{r^2} = F$$

From the expression for electric force F:

$$F = k\frac{q^2}{r^2}$$

it is possible to "derive" the equation for the electric field potential φ:

$$\frac{F}{q}r = k\frac{q}{r} = \varphi$$

If we now divide both sides of the resulting equation by time t:

$$\frac{F}{q}\frac{r}{t} = E_T v = E_T c = \frac{\varphi}{t}$$

and differentiate the resulting expression:

$$\frac{1}{c}\frac{\varphi}{t} = E_T$$

then we see the following expression of a differential equation:

$$\frac{1}{c}\frac{\partial\varphi}{\partial t} = -div\vec{A} \neq E_T$$

which appears in the electromagnetic field potential equations.

If we consider the square of the differential, we get the Laplace operator Δ:

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

If the presented expression is equal to zero: $\Delta\varphi = 0$ or $\Delta\varphi = -4\pi\rho$, then it is Poisson's equation. According to this, the following equation should hold:

$$\frac{1}{c}\frac{\partial\varphi}{\partial t}=\left(\frac{\partial}{\partial x}+\frac{\partial}{\partial y}+\frac{\partial}{\partial z}\right)\varphi$$

which gives us the above expression in the following form:

$$\left(\frac{\partial}{\partial x}+\frac{\partial}{\partial y}+\frac{\partial}{\partial z}\right)\varphi=-div\vec{A}$$

However, from the Laplace operator we get the equation:

$$\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+\frac{\partial^2}{\partial z^2}\right)\varphi-\frac{1}{c^2}\frac{\partial^2\varphi}{\partial t^2}=0$$

If this equation is expressed as follows:

$$\Delta\varphi-\frac{1}{c^2}\frac{\partial^2\varphi}{\partial t^2}=-4\pi\rho$$

where ρ is the charge density, it is a vector potential in the presence of charges. However, if the vector potential equals zero:

$$\Delta\varphi-\frac{1}{c^2}\frac{\partial^2\varphi}{\partial t^2}=0$$

then it is a wave equation in which the presence of charges is no longer taken into account. Since Maxwell's fourth equation is expressed as: $div\vec{E}=4\pi\rho$, it gives the vector potential equation:

$$\Delta\varphi-\frac{1}{c^2}\frac{\partial^2\varphi}{\partial t^2}=-4\pi\rho$$

in the following form:

$$\frac{1}{c^2}\frac{\partial^2\varphi}{\partial t^2}-\Delta\varphi=div\vec{E}=\frac{\partial E_x}{\partial x}+\frac{\partial E_y}{\partial y}+\frac{\partial E_z}{\partial z}$$

Above we stated that all electromagnetic waves in the universe are actually exactly the same in their physical nature. It can be seen from mathematics that an electromagnetic wave propagating in vacuum

$$div\vec{E}=\frac{\partial E_x}{\partial x}+\frac{\partial E_y}{\partial y}+\frac{\partial E_z}{\partial z}=0$$

is actually exactly the same wave as an electromagnetic wave caused by changes in electric charges:

$$div\vec{E}=\frac{\partial E_x}{\partial x}+\frac{\partial E_y}{\partial y}+\frac{\partial E_z}{\partial z}=4\pi\rho$$

From this we can see that from one group of electromagnetic waves we can get another group of electromagnetic waves, i.e. an electromagnetic wave propagating in vacuum is physically exactly the same wave as an electromagnetic wave caused by a change in electric charge. The only difference is that one type of electromagnetic wave can propagate in vacuum regardless of the presence of a charge:

$$4\pi\rho=0$$

but another type of electromagnetic waves depends on the presence of electric charges and thus cannot propagate in vacuum:

$$4\pi\rho \neq 0$$

This is what the previous mathematical analysis shows.

Above we saw what the Laplace operator Δ is equal to:

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

or

$$\frac{\partial^2\varphi}{\partial x^2} + \frac{\partial^2\varphi}{\partial y^2} + \frac{\partial^2\varphi}{\partial z^2} = \Delta\varphi$$

However, now we see that the resulting expression is also equal to the general differential equation for waves:

$$\frac{d^2y}{dx^2} + \frac{d^2y}{dy^2} + \frac{d^2y}{dz^2} = -\left(\frac{2\pi}{\lambda}\right)^2 * y$$

or

$$\frac{d^2y}{dx^2} + \frac{d^2y}{dy^2} + \frac{d^2y}{dz^2} + \left(\frac{2\pi}{\lambda}\right)^2 * y = 0$$

This is the case if we transform respectively: $\varphi \to y$ and $\partial \to d$. It is a general differential wave equation for waves that describes any wave amplitude y. It is derived from the sinusoidal wave equation. For example, a harmonic (sinusoidal) wave traveling along the x-axis is described by the equation:

$$y = y_0 sin2\pi\left(ft - \frac{x}{\lambda}\right)$$

where y is deviation, y_0 is amplitude, and f is frequency. If the wave source oscillates sinusoidally at a point $x = 0$ and we suppose that the initial phase equals: $\varphi = 0$:

$$y = y_0 sin2\pi ft = y_0 sin\omega t$$

then this oscillation reaches the point $x = x'$ as a wave in exactly the same phase as the oscillation of the wave source was t' seconds ago:

$$y = y_0 sin\omega(t - t')$$

The phase velocity v of the wave is expressed in the equation:

$$t' = \frac{x'}{v} = \frac{x'}{f\lambda}$$

From the latter relations we get the following equation:

$$y = y_0 sin\left(\omega t - \frac{2\pi x}{\lambda}\right)$$

Let's find the second derivative of the resulting equation with respect to x:

$$\frac{dy}{dx} = y_0\left[cos2\pi\left(ft - \frac{x}{\lambda}\right)\right]\left(-\frac{2\pi}{\lambda}\right)$$

$$\frac{d^2y}{dx^2} = -y_0\left[sin2\pi\left(ft - \frac{x}{\lambda}\right)\right]\left(\frac{2\pi}{\lambda}\right)^2$$

If in the latter equation such a multiplier is equal to one:

$$\left[sin2\pi\left(ft - \frac{x}{\lambda}\right)\right] = 1$$

we will get as a result:

$$\frac{d^2y}{dx^2} = -y\left(\frac{2\pi}{\lambda}\right)^2$$

or

$$\frac{d^2y}{dx^2} + \left(\frac{2\pi}{\lambda}\right)^2 * y = 0$$

The resulting expression is the general differential equation of waves, a wave equation that describes any wave amplitude y (in case of three-dimensional space):

$$\frac{d^2y}{dx^2} + \frac{d^2y}{dy^2} + \frac{d^2y}{dz^2} + \left(\frac{2\pi}{\lambda}\right)^2 * y = 0$$

The wavenumber k is related to the wavelength λ as follows:

$$\frac{2\pi}{\lambda} = k$$

The equations for the potentials of the electromagnetic field (in this case the electromagnetic wave) are also presented in physics as differential equations:

$$\Delta\varphi - \frac{1}{c^2}\frac{\partial^2\varphi}{\partial t^2} = 0$$

and

$$\Delta A - \frac{1}{c^2}\frac{\partial^2 A}{\partial t^2} = 0$$

However, the vector potential of the electromagnetic field created by an electric charge is expressed as follows:

$$\Delta\varphi - \frac{1}{c^2}\frac{\partial^2\varphi}{\partial t^2} = -4\pi\rho$$

and scalar potential:

$$\Delta A - \frac{1}{c^2}\frac{\partial^2 A}{\partial t^2} = -\frac{4\pi}{c}j$$

The latter equations can also be expressed only in terms of the magnetic field strength H:

$$\Delta H - \frac{1}{c^2}\frac{\partial^2 H}{\partial t^2} = 0$$

and also through the electric field strength E:

$$\Delta E - \frac{1}{c^2}\frac{\partial^2 E}{\partial t^2} = 0$$

In the latter expression, we bring the equals sign to the other side of the ΔE equation and mathematically transform as follows:

$$-\Delta E = -\frac{1}{c^2}\frac{\partial^2 E}{\partial t^2} = -\frac{1}{c}\frac{\partial}{\partial t}\left(\frac{1}{c}\frac{\partial E}{\partial t}\right) = -\frac{1}{c}\frac{\partial}{\partial t} rotH = -\frac{1}{c} rot\frac{\partial H}{\partial t}$$

The obtained result in turn equals:

$$-\frac{1}{c} rot\frac{\partial H}{\partial t} = grad\ div\ E - \Delta E = rot\ rot\ E$$

in which Maxwell's first equation appears:

$$rot\ E = -\frac{1}{c}\frac{\partial H}{\partial t}$$

Maxwell's second equation is expressed in the form: $div\ H = 0$ and the third equation in case of an electromagnetic wave:

$$rot\ H = \frac{1}{c}\frac{\partial E}{\partial t}$$

and in case of an electromagnetic field:

$$rot\ H = \frac{1}{c}\frac{\partial E}{\partial t} + \frac{4\pi j}{c}$$

Maxwell's fourth equation is expressed as follows: $div\ E = 0$ and $div\ E = 4\pi\rho$. Maxwell's equations describe the entire doctrine of electromagnetism, but they are primarily the equations of classical physics.

Above we were able to derive the equation for electric field strengths in case of an electromagnetic wave:

$$\Delta E - \frac{1}{c^2}\frac{\partial^2 E}{\partial t^2} = 0$$

which, when written out, can be expressed as follows:

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right)E - \frac{1}{c^2}\frac{\partial^2 E}{\partial t^2} = 0$$

or

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right)E = \frac{1}{c^2}\frac{\partial^2 E}{\partial t^2}$$

The latter equation can actually be expressed as:

$$\frac{E}{l^2} = \frac{1}{c^2}\frac{E}{t^2}$$

from which the expression for the speed of light occurs:

$$Ec^2 = E\frac{l^2}{t^2}$$

or

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

The speed of propagation of an electromagnetic wave in vacuum exactly matches the speed of light c. However, the rate of change or creation of electric and magnetic fields in an electromagnetic wave is also equal to the speed of light c.

The member $-\frac{\partial}{\partial r}$ in the equations can be expressed as a negative grad or

$$-\left(i\frac{\partial}{\partial x} + j\frac{\partial}{\partial y} + k\frac{\partial}{\partial z}\right),$$

denoted as nabla ∇. This is because the term -∂/∂r is a vector the components of which are

$$\frac{\partial}{\partial x}, \frac{\partial}{\partial y} \ \ and \ \ \frac{\partial}{\partial z}$$

and therefore, the expression

$$E_r = -\frac{\partial \varphi}{\partial r}$$

can be expressed as a gradient of the scalar φ as follows:

$$E = -grad\varphi$$

or

$$E = -\left(i\frac{\partial \varphi}{\partial x} + j\frac{\partial \varphi}{\partial y} + k\frac{\partial \varphi}{\partial z}\right)$$

or

$$E = -\nabla\varphi$$

in which ∇ is nabla. This means that the electric field strength E is equal to the potential gradient of opposite sign. The Nabla or Hamiltonian operator ∇ is a vectorial differential operator. It is a vector the components of which are

$$\frac{\partial}{\partial x}, \frac{\partial}{\partial y} \ \ and \ \ \frac{\partial}{\partial z}$$

and therefore we get nabla as follows:

$$\nabla = i\frac{\partial}{\partial x} + j\frac{\partial}{\partial y} + k\frac{\partial}{\partial z}$$

Alone, this vector has no meaning, but it only acquires physical meaning when multiplied by a simple scalar or vectorial function. For example, we can get the gradient of a function by multiplying the vector ∇ by the scalar φ, whereby the result is a vector:

$$\nabla\varphi = i\frac{\partial \varphi}{\partial x} + j\frac{\partial \varphi}{\partial y} + k\frac{\partial \varphi}{\partial z}$$

in which the electric field potential φ is expressed as the following function:

$$\varphi = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

The field potential is described by a differential equation, which is the gradient or grad. The gradient is denoted by a symbol called nabla:

$$\nabla\varphi = grad\varphi$$

However, we can get the divergence of the vector A by multiplying the vector ∇ scalar by the vector A, whereby the result is a scalar:

$$\nabla A = \nabla_x A_x + \nabla_y A_y + \nabla_z A_z = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z}$$

We can then multiply one component (x) of the vector rotA vectorially by the vector A, resulting in a vector one component of which is, for example, the following expression:

$$(\nabla A)_x = \nabla_y A_z - \nabla_z A_y = \frac{\partial A_z}{\partial y} - \frac{\partial A_y}{\partial z}$$

∇ is a differential operator. A vectorial function is the gradient of some function φ. For example:

$$divgrad\varphi = \nabla(\nabla\varphi) = (\nabla\nabla\varphi) = \left({\nabla_x}^2 + {\nabla_y}^2 + {\nabla_z}^2\right)\varphi = \frac{\partial^2\varphi}{\partial x^2}\frac{\partial^2\varphi}{\partial y^2}\frac{\partial^2\varphi}{\partial z^2} = \triangle\varphi$$

where △ is the Laplace operator. Accordingly, the entire electric field is described by Poisson's equation:

$$\Delta\varphi = -4\pi\rho \quad \text{or} \quad \text{divgrad}\varphi = -4\pi\rho,$$

where $\text{div}\vec{E} = 4\pi\rho$ and $\vec{E} = -\text{grad}\varphi$. The circulation of an electric field (i.e. an electrostatic field) is zero for any contour:

$$\oint E_r\, dr = 0$$

The latter equation is only valid for electrostatic field and is also consistent with the following mathematical expression:

$$rotgrad\varphi = (\nabla, \nabla\varphi) = (\nabla\nabla)\varphi = 0$$

The latter expression means that the cross product of a vector with itself is zero.

2.6.2 Maxwell's fourth equation

Above, Maxwell's equations were "derived" in a "peculiar way", in which the physics of electromagnetism was shown to be derived only from the speed of light, electric and magnetic constants. However, in conventional physics, Maxwell's equations are derived from different differential equations. For example, Maxwell's fourth equation can be derived from the definitions of magnetic flux and vector field flux. We will show this briefly in the following.

The magnetic flux Φ indicates the extent to which the magnetic field lines pass through the observed surface due to the size and position of this surface in the magnetic field:

$$\Phi = BScos\beta = B_nS = BS$$

In this case, the surface is perpendicular to the B vector: $cos\beta = 1$. From Ampere's law, we get the definition of magnetic induction B:

$$B = \frac{F}{Il}$$

in which the magnetic field is perpendicular to the current direction: $sin\alpha = 1$. Therefore, we can express the magnetic induction B in the magnetic flux equation as follows:

$$\Phi = \frac{F}{I}\frac{S}{l}$$

The definition of the vector field flux can be seen from the latter expression:

$$\Phi(Il) = FS$$

or

$$\Phi_F = FS$$

which is similar to the definition of magnetic flux:

$$\Phi = BS$$

The only difference is that, for B, the magnetic induction flux is seen through the surface S, but for F the vector field flux is seen through the surface S. We can use the form:

$$d\vec{S} = \vec{n}dS$$

in which there is a surface normal vector: $|\vec{n}| = 1$. According to this, we get a differential equation:

$$d\Phi_F = \vec{F}d\vec{S} = \vec{F}\vec{n}dS = F_ndS$$

which appears as an integral as follows:

$$\Phi_F = \iint\limits_S \vec{F}d\vec{S} = \iint\limits_S F_n\, dS$$

The member F_n is the normal projection of $\vec{F}$-i in the direction of $\vec{n}$. For a closed surface, the integral can be presented as follows:

$$\Phi_F = \oiint\limits_S \vec{F}d\vec{S}$$

The famous Grauss-Ostrogradsky equation can be seen from the latter:

$$\oiint\limits_S \vec{F}d\vec{S} = \iiint\limits_V div\vec{F}dV$$

In the vector field flux expression, we can consider the field strength instead of the force: $\vec{F} \rightarrow \vec{E}$. In this case, in the expression for the vector field flux:

$$\Phi_E = \oint\!\!\!\oint_S \vec{E} d\vec{S}$$

an E-vector $\vec{E}$ appears instead of the force vector $\vec{F}$. In this case, the integral equation is equal to the constant e:

$$\oint\!\!\!\oint_S \vec{E} d\vec{S} = const \sum_i e_i = const\ e$$

The constant e is also related to the differential equation:

$$de = \rho dV$$

in case of integrating of which we get:

$$e = \iiint \rho(\vec{r}) dV$$

This means that the constant e is related to the charge density ρ. According to this, we can integrate the vector field flux expression as follows:

$$\oint\!\!\!\oint_S \vec{E} d\vec{S} = const \iiint \rho dV = \iiint div\vec{E} dV$$

This shows a clear connection:

$$div\vec{E} = const\rho$$

in which the constant is equal to:

$$const = 4\pi$$

The result is Maxwell's fourth equation, which is one of the four fundamental equations to describe the entire physics of electromagnetism:

$$div\vec{E} = 4\pi\rho$$

However, since the electric field strength $\vec{E}$ is related to the gradient of the potential φ:

$$\vec{E} = -grad\varphi$$

then we can also write Maxwell's fourth equation in the following form:

$$divgrad\varphi = -4\pi\rho$$

or, using the Laplace operator:

$$\Delta\varphi = -4\pi\rho$$

Such an equation is called Poisson's equation in physics, which applies to the presence of electric charges. However, in the absence of charges, the form of this equation is:

$$\Delta\varphi = 0$$

Such an equation is a harmonic equation.

Poisson's equation (in the absence of electric charges):

$$\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+\frac{\partial^2}{\partial z^2}\right)\varphi=0$$

can be written in the following form:

$$\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+\frac{\partial^2}{\partial z^2}\right)\varphi-\frac{1}{c^2}\frac{\partial^2\varphi}{\partial t^2}=0$$

or

$$\Delta\varphi-\frac{1}{c^2}\frac{\partial^2\varphi}{\partial t^2}=0$$

since in such an expression we can also take into account temporal changes. This is called the d'Alembert operator, which can be denoted as:

$$\Box\varphi=0$$

The Laplace operator Δ only takes into account spatial changes, but d'Alembert's operator also takes into account temporal changes.

2.7 The first generation technical concept for creating a tunnel in spacetime

2.7.1 United States Patent and Trademark Office (USPTO)

The invention, which allows creating a human-sized annular tunnel in space-time, has been attempted to be patented in the United States Patent and Trademark Office (USPTO, website: https://www.uspto.gov). The corresponding patent applications by Marek-Lars Kruusen have been filed in 2023. Patent application number is: 18/339,426; and title of invention: „*Method and equipment for creating a tunnel in spacetime or wormhole*“.

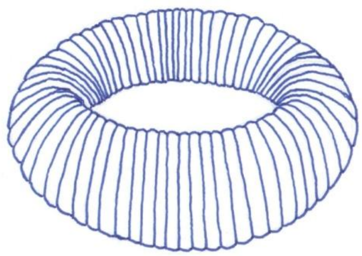
The invention belonging to the field of engineering industry allows artificially creating a loop-shaped tunnel in spacetime, which, according to physics theories, allows a person to teleport in time and space. The main purpose of the machine is to create an electromagnetic field around the machine that changes exactly at the speed of light c. According to Albert Einstein's theory of relativity and Marek-Lars Kruusen's physics theory of time travel, an electromagnetic field changing at the speed of light c should create a short-term closed trapped surface in spacetime, which can also be interpreted as a tunnel in spacetime.

However, only the engineering-technical part is presented in the patent application, which should convincingly demonstrate the creation of a tunnel in spacetime, and that's it. According to the Patent Act, only engineering and technical solutions are patentable, not physical theories. Therefore, the theoretical physics part of how a tunnel in spacetime causes a person to teleport in time and space remains unreported in the patent application. This is already a theoretical part, which is not a patentable object according to the patent law.

Physics theories that would show and describe how, for example, a tunnel in spacetime makes a person or an entire machine teleport in time and space, are presented in this publication.

2.7.2 An invention

The invention belongs to the field of transport technology industry, i.e. it is intended for transporting a human being in time and space, which does not take time. This means that the invention allows the artificial creation of tunnels in spacetime that can be used to teleport a person in time and space. Figure:



The transportation technology industry is one of the world's largest economic sectors. The types of inventions that belong to this economic sector are, for example, cars, airplanes, helicopters, ships, rockets, etc. All these inventions use diesel, gasoline or electric engines and their purpose is mostly to transport people or goods in air, land, water or space. The invention described below is also intended for transporting a person, but in time and space, which does not take time. This is made possible by a tunnel in spacetime, which the previously listed inventions cannot create. The loop-shaped tunnel in spacetime is created by a rotating ring machine, which has its own machine and control room and electromechanical components that generate the electromagnetic field. This invention also differs from the previously listed ones in that it is a human-sized rotating machine, which does not appear in any other known invention.

The invention described below is similar to an elevator used in high-rise buildings, since in case of both of them, a person enters an enclosed space, which is transported to another location by means of wheels and belts. But the difference is that while an elevator only carries a person up or down vertically, a ring machine carries a person along a ring-shaped tube.

The most important goal of the invention is to artificially create a loop- or ring-shaped tunnel in spacetime, which, according to theoretical physics, would allow a person to teleport in time and space. This is achieved by such an incredibly simple technical solution, which is presented at length and in depth in the time travel theory (1)(2).

All drawings are made with so-called "free hand", i.e. "by hand". This means that no drawing programs or drawing techniques have been used to make the drawings. Therefore, the drawings may not be on a very accurate scale compared to reality. All drawings were made by the author of this work.

> Since no drawing programs or specific drawing techniques have been used in making the drawings, the scales of the various drawings are therefore not accurate. For example, the elements of the machine can have different sizes or even different thicknesses in different drawings. However, the accuracy of the scale of the drawings is not really that important here, but it is important to convey the principle and essence of physical and engineering-technical

understanding.

The technical solution for creating tunnels in spacetime presented in this work differs from the technologies on the market in that the ring machine creates a ring-shaped tunnel in spacetime, i.e. a ring-shaped wormhole, with much simpler technical means and does not consume large amounts of energy. This is one of the main differences - the product does not consume large amounts of energy compared to devices used in rocket technology. The energy consumption of a production-ready machine is many times lower compared to other products in the space technology sector, which is why it is also much "greener".

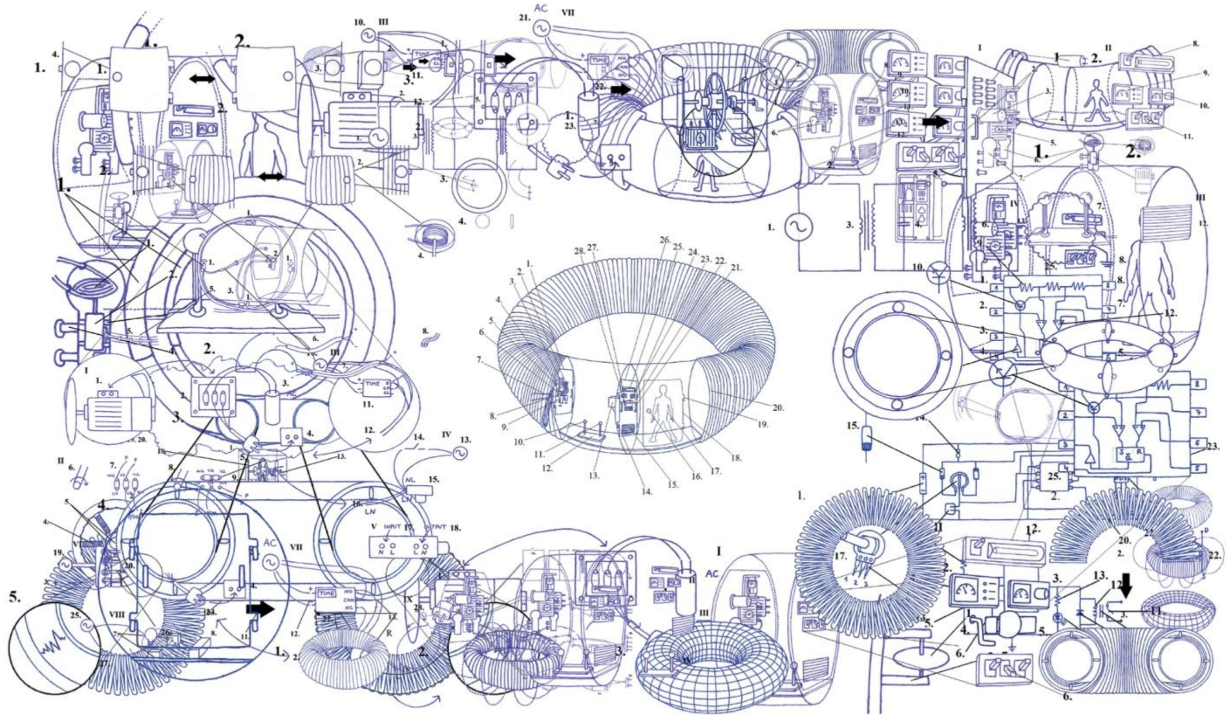
Another big difference is that the ring machine presented in this work is completely unique. This means that there is no product on the market that would allow artificially creating a tunnel in spacetime or a wormhole. Not even NASA or private space companies have this kind of technical concept described in this work. It is the world's first technological concept to create a tunnel in spacetime that a person can pass through and that would be technically controllable.

Any technology that creates a wormhole is extremely necessary for the market, as it allows space travel to be made much easier, economically cheaper and also "greener". As the space industry is on the rise all over the world, so any company would benefit greatly from the space industry. Any company could become a part of the space industry sector, as billions of US dollars move in this economic sector every year.

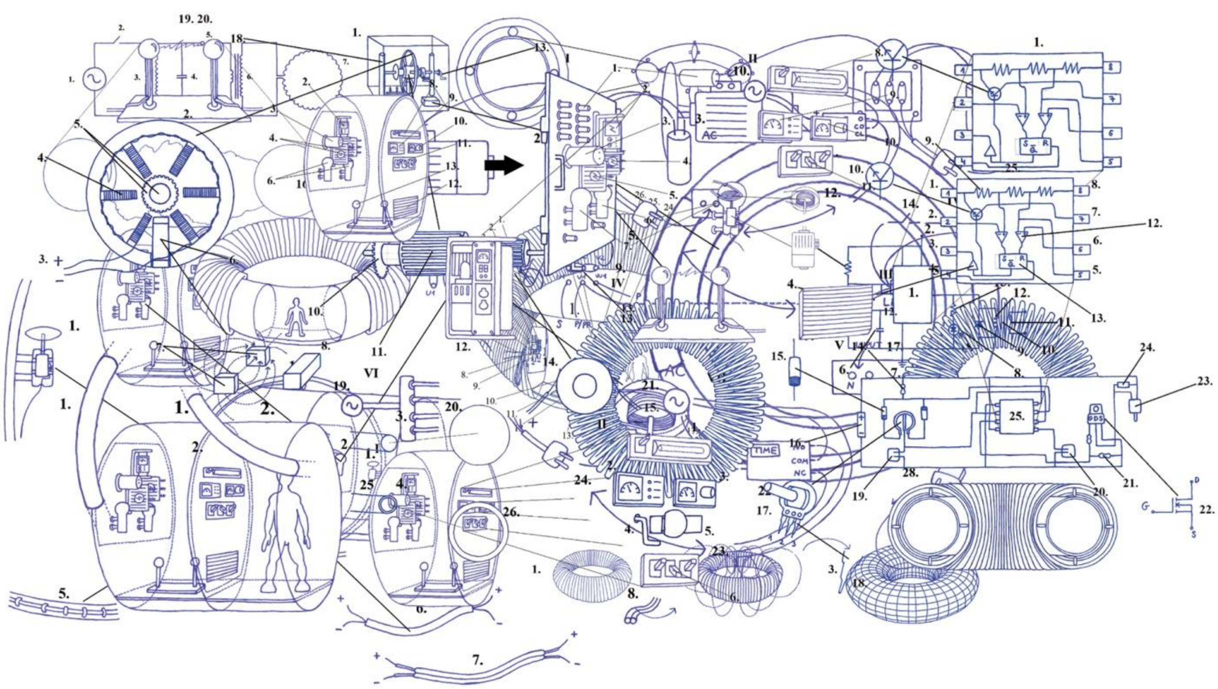
In theoretical physics, a tunnel in spacetime is a physical "object" through which it is theoretically possible to travel through time and/or teleport in space. The following description provides us with a practical opportunity to create a spacetime tunnel, allowing us to test the validity of time travel physics theories. However, the construction and operational principles of the machine are only partially presented, as the focus is primarily on the external aspects of the machine and its main objectives.

> Developing this specific technology will create new opportunities to explore human history and also to move in space.

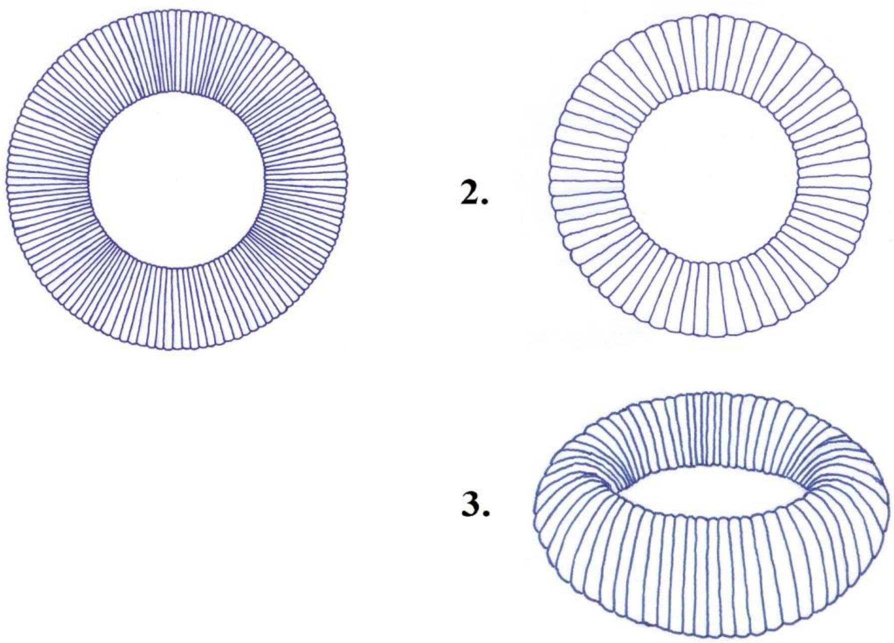
The device/machine consists of a large number of elements of the circuit, all of which are closely related to each other. This is shown in the following figure, in the center of which you can see the compact machine and, around it, the elements of the circuit that make up the machine:



In order to save space, all elements of the machine are shown in one diagram:



In this case, a toroid or "toroid-like machine" is the structural basis of the machine for creating a loop-shaped tunnel in spacetime, figure:

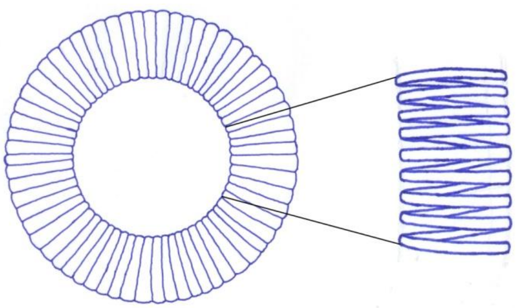


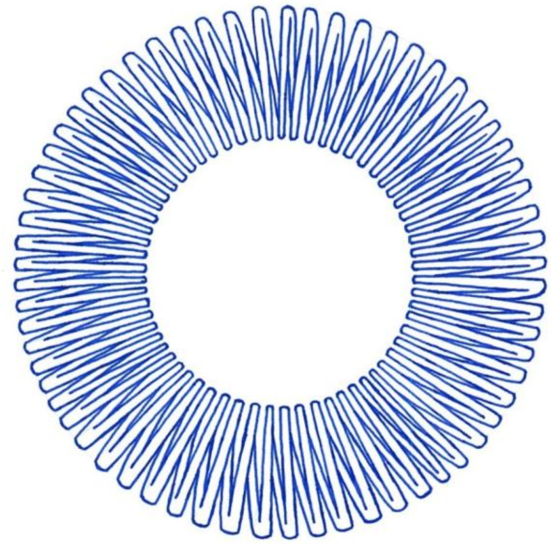
1.
2.
3.

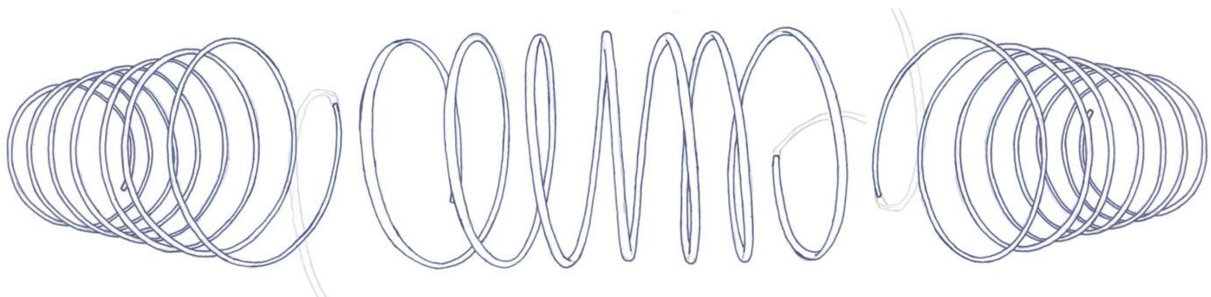
1. Top view of a toroid with a very high ring density (i.e. the number of rings).
2. Top view of the toroid, the density of the rings of which is a little smaller than the previous one.
3. Side view of another toroid drawing.

NOTE: It may look like we have two different toroids. In fact, it is not so. It is still only one toroid, the number of circles of which can be easily determined in different ways. That's what these drawings show.

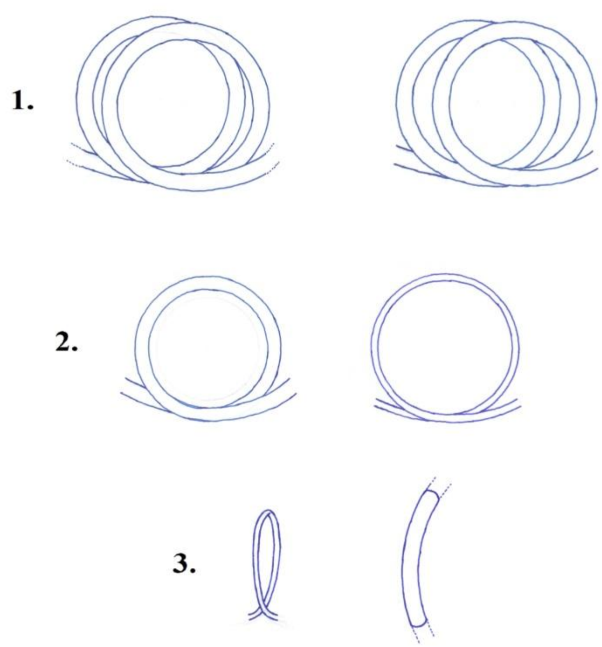
The toroid is formed by circles with "air gaps" between them. The figure:







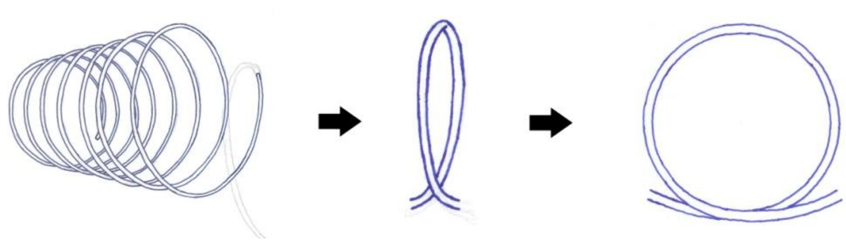
The toroid is formed by rings, which are all connected to each other and have air gaps between them. Figure:



1. An example in which the two turns of the toroid are bound/connected to each other.
2. A sample of one circle of a toroid (the first one is thicker, the second is thinner). The size and coarseness/thickness of the toroid circles can be freely determined. Therefore, the drawings are presented in two different ways.

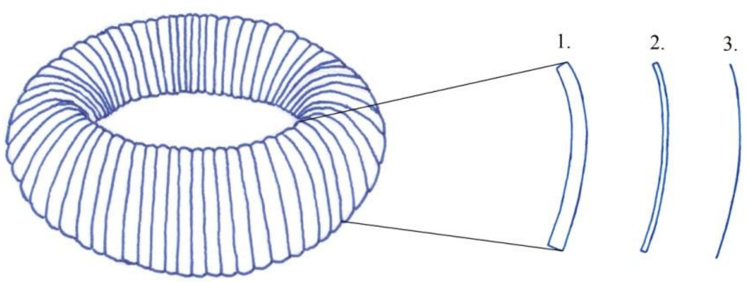
   The thicker the wire or tube, the smaller the energy loss caused by the surface effect (as heat) at high frequencies in the case of electric current.

3. The first drawing – side view of one ring of a toroid

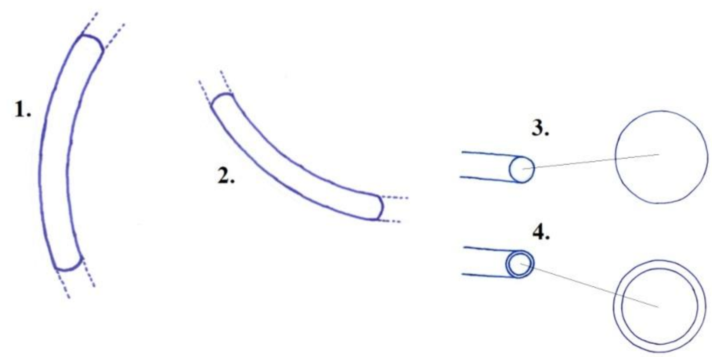


and another drawing – the toroid is made of an electrically conductive material, for example a metal tube.

The tubes that make up the toroid can have very different diameters, or thicknesses. This means that no fixed dimensions have been designated to the tubes of the toroid. For example, in the following figure, three different variants of the thickness of the toroid tubes are visually shown (1, 2 and 3, respectively):



A tube of a ring, which all together forms the entire toroid, can be "empty" or "full" from inside. Figure:

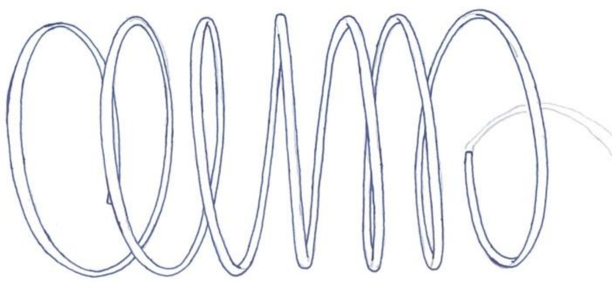


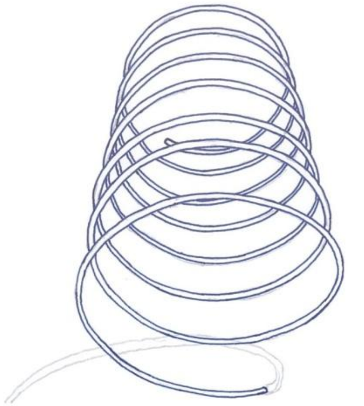
1. View of the tube of the ring 1
2. View of the tube of the ring 2

3. The tube can be full from inside
4. The tube can be empty from inside

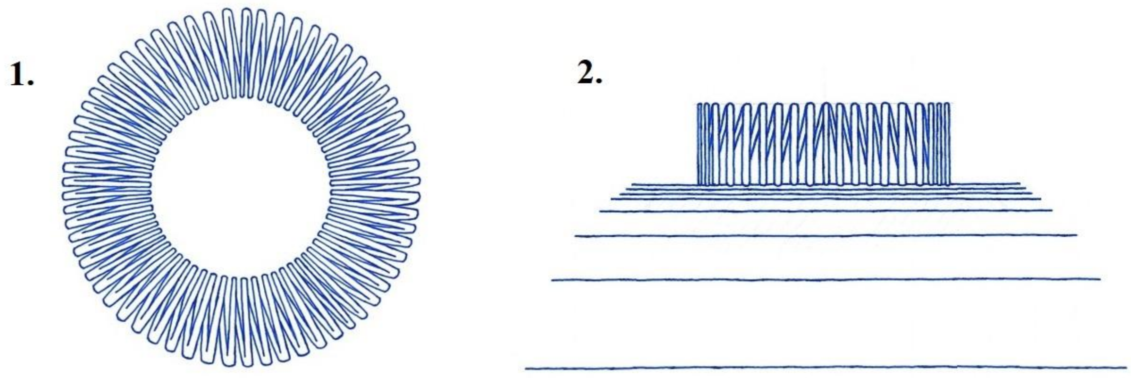
Toroid (i.e. toroid turns) form the so-called "framework" of this machine, on which everything else related to the construction of the machine rests. Therefore, the frame of the machine must be made of strong material and at the same time it must be electrically conductive. A metallic compound of some kind is very suitable for this.

At this point, we can point out one example of circles that would very well illustrate the toroidal circles described above. They are made from "one" metal pipe. The images displayed are as follows:



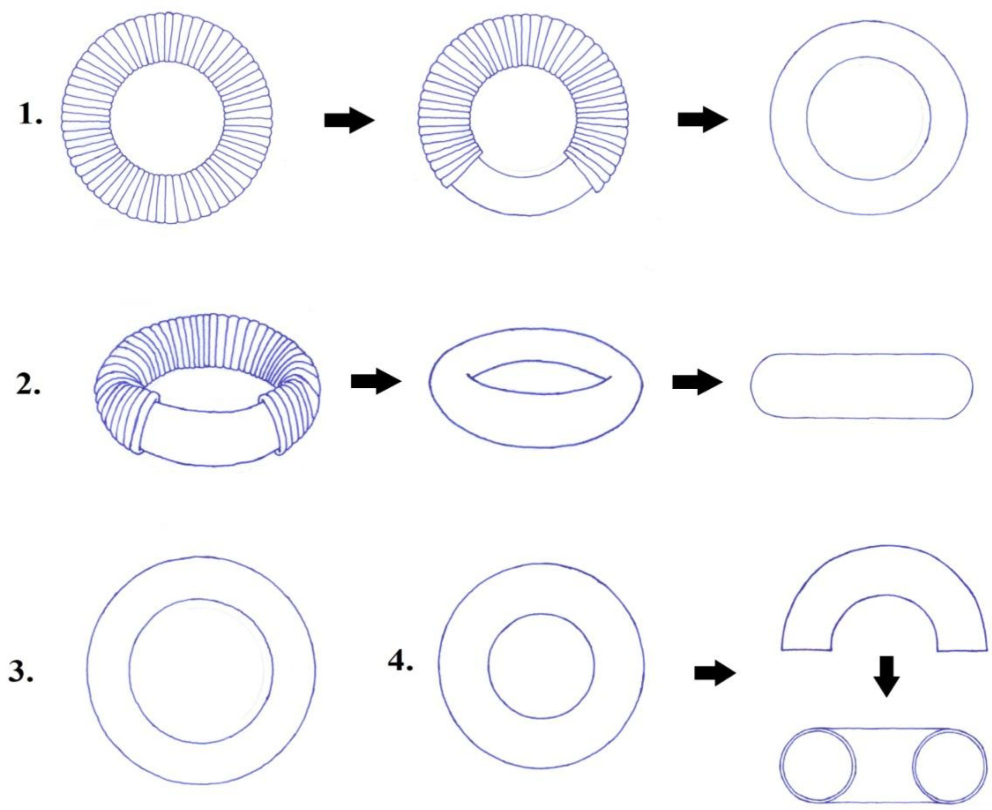



The toroid is located on the ground, which means that the toroid is in direct contact with the ground. Figure:

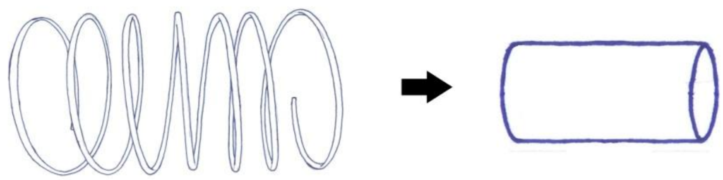


1. Top view of the toroid
2. Side view of the toroid, in which case the toroid can be seen in contact with the ground.

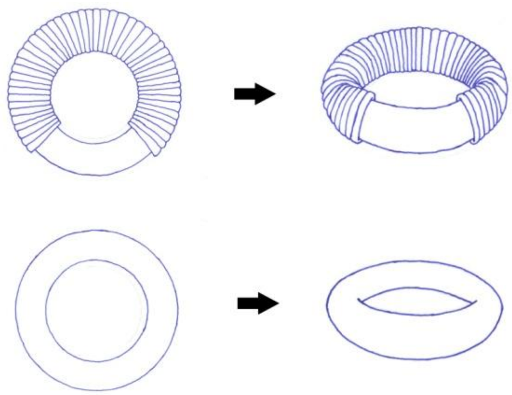
Inside the toroid is a ring-/doughnut-shaped tube that is hollow inside and is also made of an electrically conductive material such as metal. Figure:



1. A ring-/doughnut-shaped tube is located inside the toroid. The placement indicates the inner part of a hole of the toroid on the second figure.



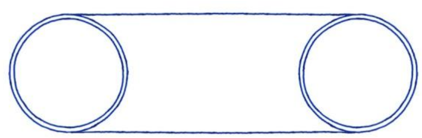
2. Different side views of the toroid and the tube inside it.



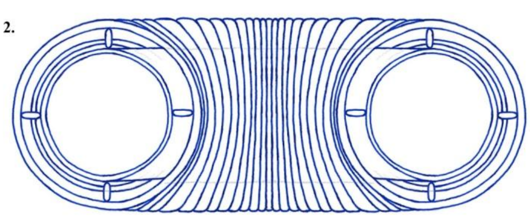
3. Top view of the tube inside the toroid.
4. Cross-section of the tube inside the toroid.

In the following, we present a much more detailed and larger drawing of the cross-section of the toroid and the tube inside it:

1.



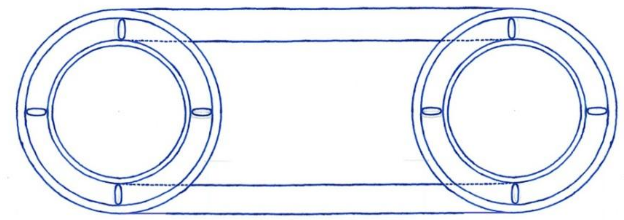
2.



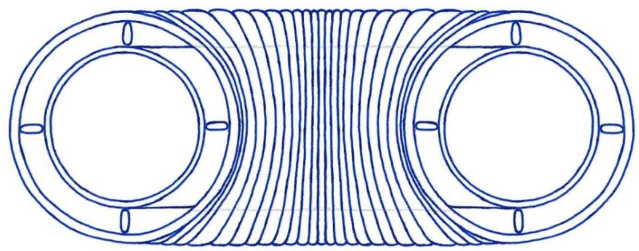
1. Cross-section of the tube inside the toroid.
2. Cross-section of the toroid and the tube inside it, wheels can be seen on the figure as well. The drawing shows that the tube is surrounded by (i.e. “covered” by) the toroid.

The following shows different cross-sectional drawings of the toroid and the tube inside it (with wheels):

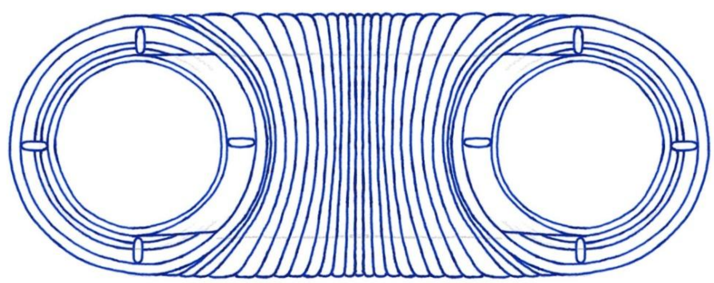
1.



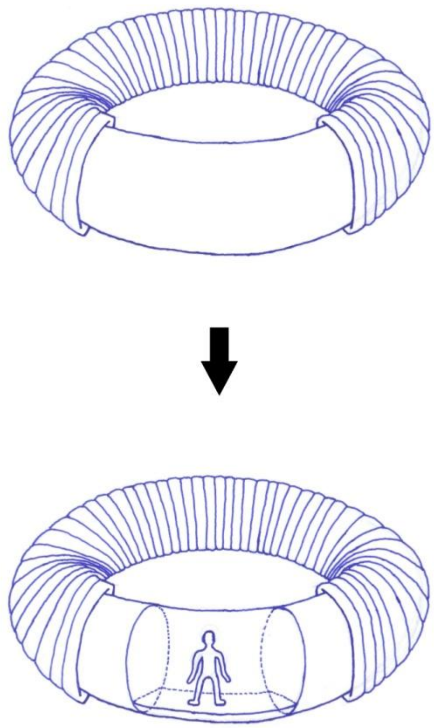
2.



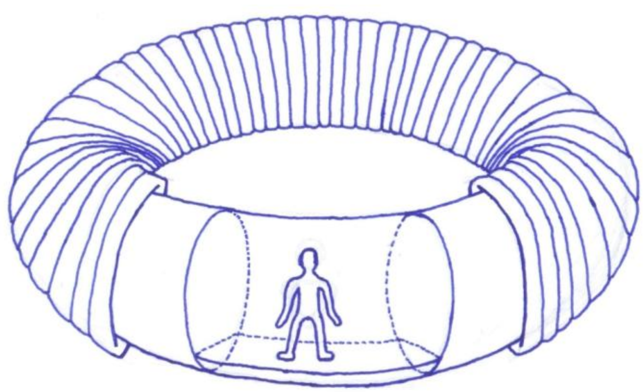
3.



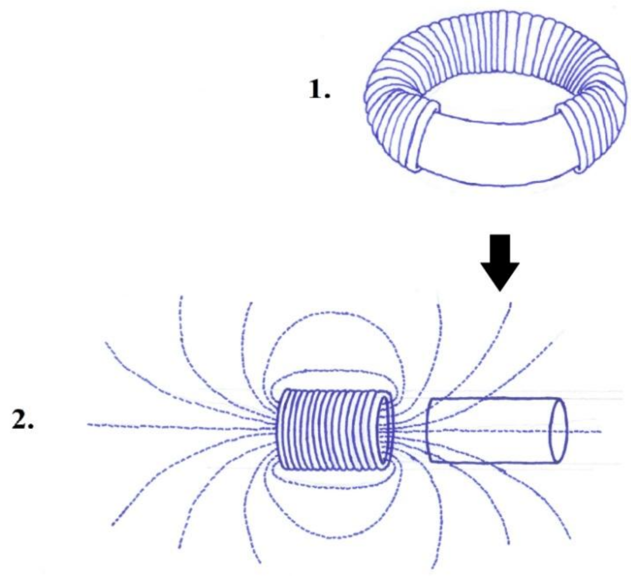
The tube inside the toroid must move (i.e. rotate). The tube inside the toroid has a special room that a person can enter. Figure:



At this point, it is worth noting that the image of a person in the various drawings shows the approximate scale (i.e. size) of the entire ring machine. Figure:



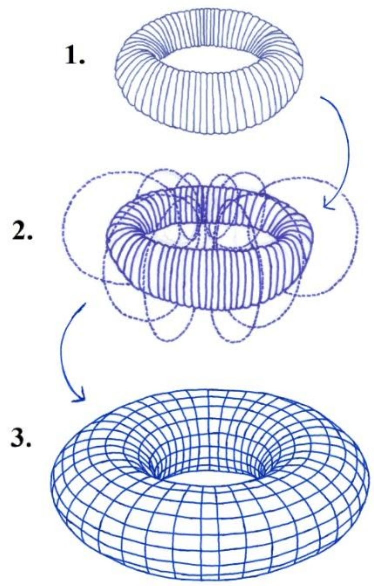
The physical meaning of the rotation of the tube lies in the well-known phenomenon of "electromagnetic induction". For example, if an electric current passes through the rings of the toroid and at the same time the tube starts to move (i.e. rotate), then a changing magnetic field is created everywhere at the same time in the space surrounding the toroid. Figure:



1. Opening of a toroid showing the tube inside.
2. The magnetic field of the coil changes as the metal tube moves through the coil.

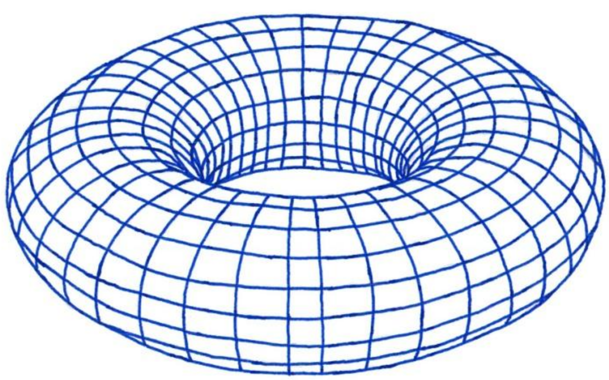
> The movement of a coil of wire in a magnetic field can cause a change in the magnetic flux due to electromagnetic induction. This is why it can happen that if an electric current passes through the toroid's rings and at the same time the tube starts to move (i.e. rotate), a changing magnetic field is created everywhere at the same time in the space surrounding the toroid.
>
> Electromagnetic induction is the generation of an electric current in a conducting closed coil of wire when the magnetic flux passing through the surface of this coil of wire changes. Between the ends of a wire section moving in a magnetic field, an electric voltage, or electromotive force of induction, occurs when there is no current in the wire. Electric current caused by electromagnetic induction is called induction current.

In the space surrounding the toroid, a changing magnetic field is created everywhere at the same time, which is also accompanied by the short-term creation of a toroid-/tube-shaped tunnel in spacetime. Figure:



1. If no electric current passes through the rings of the toroid, then no field is created in the space surrounding the toroid.
2. When an electric current passes through the turns of the toroid, a magnetic field is created in the space surrounding the toroid.
3. If the toroid tube starts to rotate, a changing magnetic field is created everywhere at the same time in the space surrounding the toroid. Since the magnetic field always changes exactly at the speed of light c, it is also accompanied by the short-term emergence of a toroid-/tube-shaped trapped surface in spacetime. It can be visualized as a loop-shaped tunnel in spacetime that occurs for an extremely short period of time.

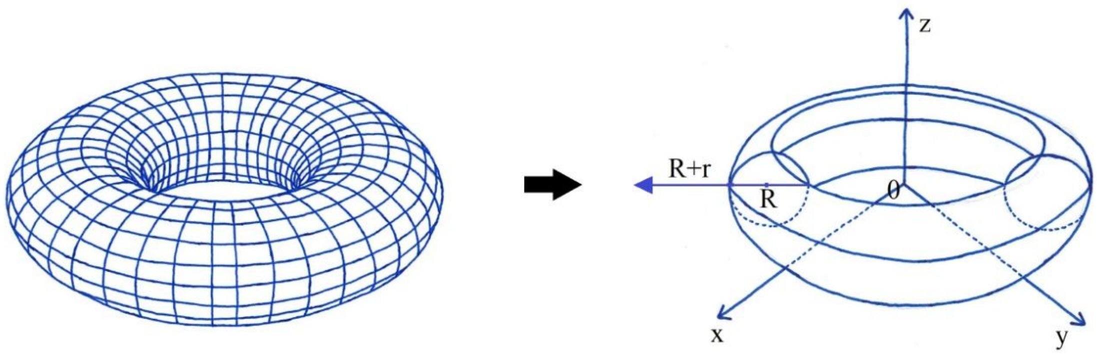
When the tube inside the toroid starts to move or rotate "during electric current", this results in a "changing magnetic field" around the toroid. In this case, a magnetic field resulting from the electric current occurs firstly, and then a changing magnetic field resulting from the rotation of the tube. A change in the magnetic field creates an (eddy) electric field and the rate of change is exactly equal to the speed of light c in a vacuum. Due to the rate of change of the external magnetic field of the toroid, which is exactly equal to the speed of light c, a ring-shaped tunnel in spacetime is created around the toroid that enables time travel. Figure:



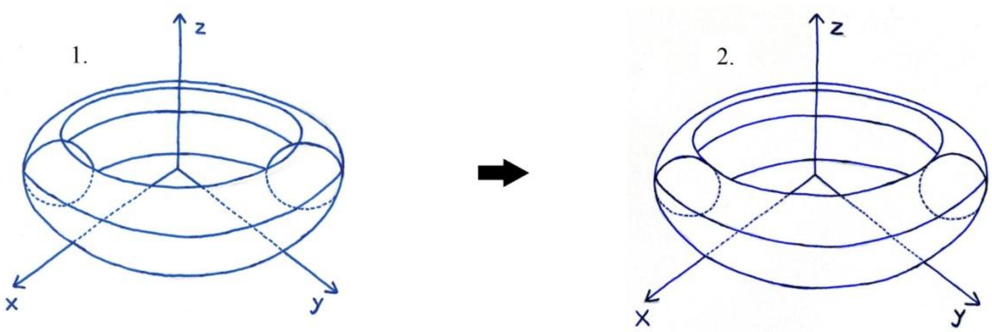
It should be noted here that the characteristic values concerning the energy field generated by the ring machine are not important. The characteristic quantities of a physical field are, for example, field energy and force. Their numerical values are not important in this case, since we only care

> about the fact that the field changes and/or is created everywhere at the same time exactly at the speed of light c. This is important. Since the ring machine is larger than a person, the energy of the resulting or changing field is still very large compared to one electron volt. This means that it is a macroscopic field, not a micro or quantum field.

The resulting annular tunnel in spacetime or an annular trapped surface of spacetime is in the form of such an inverse surface, which is called a "torus" in higher mathematics. Figure:



> NOTE: The two circles shown in the drawing of the torus (1) must actually be to the correct scale (2). Figure:



In mathematics, such a surface is called an inverse surface, which is created by the rotation of a planar line around the axis of a straight or inverse surface located on the plane of this line. The rotating line in each of its positions is called the meridian of the inverted surface. The circles formed by the rotation of a fixed point on the meridian are called parallels. If the meridian lies on the yz plane, which means that if the meridian is with a given system:

$$\begin{cases} F(y,z) = 0 \\ x = 0 \end{cases}$$

and the axis of rotation is the z-axis, then the equation of the surface of revolution is:

$$F\left(\pm\sqrt{x^2+y^2}, z\right) = 0$$

A torus is a ring surface or inverse surface (i.e. a toroid), which is created when a circle rotates around a line that is on the same plane as the circle and does not intersect with it. For example, if a circumference specified on the yz plane with an equation

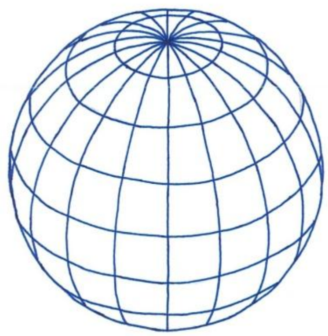
$$(y-R)^2 + z^2 = r^2$$

(in which $R > r$) turns around the z-axis, the equation of the torus obtains the following form:

$$\left(\sqrt{x^2 + y^2} - R\right)^2 + z^2 = r^2$$

The surface area of a torus S is expressed as $S = 4\pi^2 Rr$ and the volume of an annulus confined by it V is expressed as $V = 2\pi^2 Rr^2$.

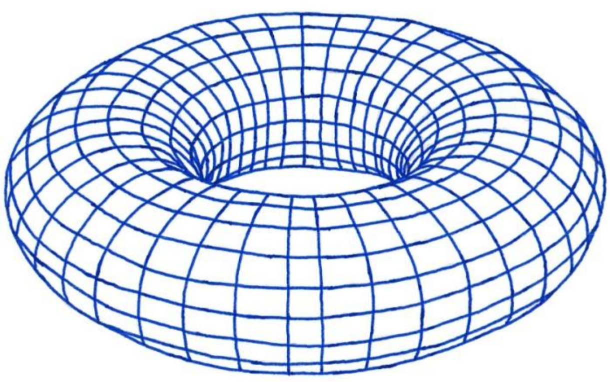
As a comparison it can be said, for example, that if the trapped surface of spacetime of a non-rotating Schwarzschild black hole is exactly spherical:



with radius r:

$$r = \frac{2GM}{c^2} = \sqrt{\frac{S}{4\pi}}$$

then this trapped surface of spacetime is torus-shaped:



with radius r:

$$r = \sqrt{z^2 + \left(\sqrt{x^2 + y^2} - R\right)^2}$$

The physical nature is exactly the same in case of these two different objects, but the geometric shape in space is different.

A torus is also described by such an equation presented in mathematics:

$$(x^2 + y^2 + z^2 + a^2 - r^2)^2 = 4a^2(x^2 + y^2)$$

where r is the radius and x, y, and z are the coordinates. We will not derive or prove this equation here, but the mathematical definition of a can be seen from this equation. We will show this briefly as follows. To do this, we square both sides of the equation:

$$x^2 + y^2 + z^2 + a^2 - r^2 = 2a\sqrt{x^2 + y^2}$$

Let us transfer the members with a to one side of the equation:

$$a^2 - 2a\sqrt{x^2 + y^2} = r^2 - x^2 - y^2 - z^2$$

Let us bring a in front of the parenthesis:

$$a\left(a - 2\sqrt{x^2 + y^2}\right) = r^2 - x^2 - y^2 - z^2$$

and as a result we get:

$$-2\sqrt{x^2 + y^2} = \frac{1}{a}(r^2 - x^2 - y^2 - z^2) - a$$

or

$$2\sqrt{x^2 + y^2} = a - \frac{1}{a}(r^2 - x^2 - y^2 - z^2)$$

In the resulting equation we can see that it contains the Pythagorean theorem:

$$\sqrt{x^2 + y^2} = l$$

and consequently we can write:

$$r^2 - x^2 - y^2 - z^2 = r^2 - r^2$$

This gives us the final form of the equation as follows:

$$2l = a - \frac{1}{a}(r^2 - r^2)$$

If the following condition is valid: $r^2 - r^2 = 0$, we will obtain as a definition of a:

$$a = 2\sqrt{x^2 + y^2} = \sqrt{x^2 + y^2} + \sqrt{x^2 + y^2}$$

However, if the following condition is valid: $r^2 - r^2 \neq 0$, we will get from the equation derived above:

$$2\sqrt{x^2 + y^2} = a - \frac{1}{a}(r^2 - x^2 - y^2 - z^2)$$

and, taking into account the latter definition, the following expression for the definition:

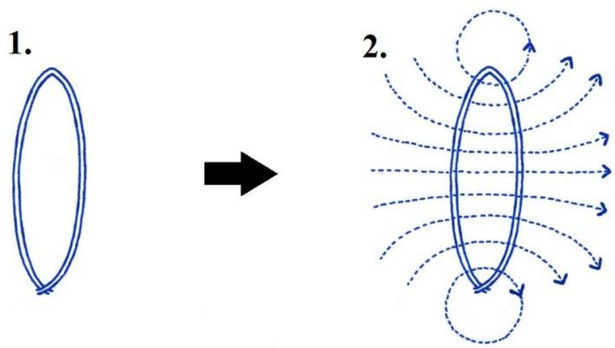
$$a = \sqrt{x^2 + y^2} + \sqrt{x^2 + y^2} - \frac{(r^2 - x^2 - y^2 - z^2)}{\sqrt{x^2 + y^2} + \sqrt{x^2 + y^2}}$$

It is a mathematical definition than can only be seen from equation of a torus.

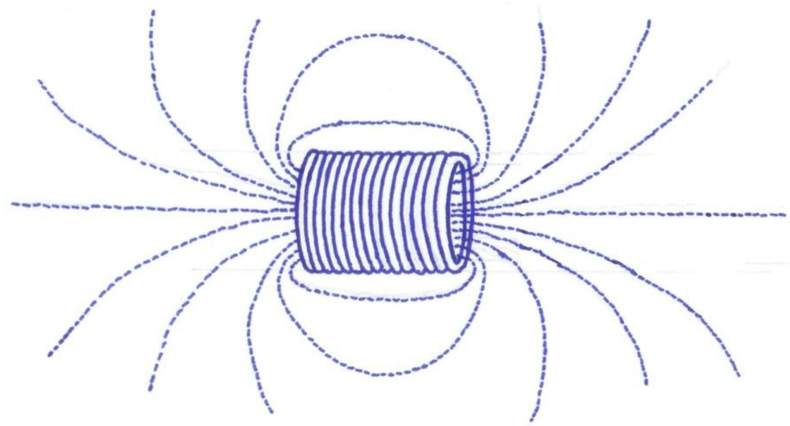
2.7.3 The solenoidal electric field of a ring machine and a tunnel in spacetime

The physical meaning of the rotation of the toroid tube lies in the well-known phenomenon of "electromagnetic induction". For example, if an electric current passes through the circuits of the toroid and at the same time the tube starts to move (i.e. rotate), then a changing magnetic field is created everywhere at the same time in the space surrounding the toroid. The following material explains and analyses the latter statement more thoroughly.

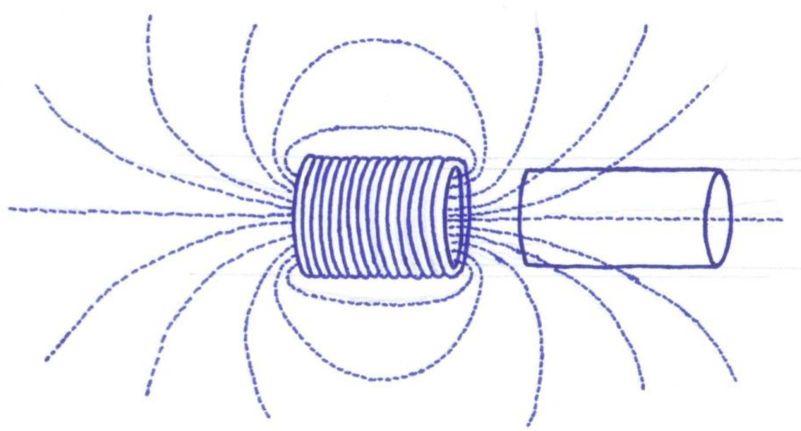
For example, let us assume that we have such a circular wire, or wire twist (1), in which no electric current flows. If we bring a permanent magnet close to a coil of wire, which eventually passes through this coil of wire, then according to Faraday's law of induction, a unit induction current is generated in the coil of wire, which creates a magnetic field around the coil of wire (2). If instead of a permanent magnet there were a current-carrying coil, then when the current-carrying coil is moved relative to the coil of wire and also when passing through it, a unit induction current would also be generated in the coil of wire. It must be emphasized here that the induction current exists only as long as the coil of wire moves relative to the lines of force of the permanent magnet or current-carrying coil. Figure:



In many electrical devices, coils with electric current are used as magnetic field generators. In the coil, the wire is tightly wound on a plastic or cardboard tube. When the ends of the coil are connected to a current source, an electric current is generated in it. A magnetic field is created in and around the coil. Figure:



A current-carrying coil has a magnetic north pole at one end and a magnetic south pole at the other end. The magnetic field of a current-carrying coil can be strengthened by placing an iron core inside the coil. Figure:



The effect of a coil with an iron core on iron objects is greater, because in the magnetic field of the current-carrying coil, the iron core is magnetized, or becomes a magnet. The magnetic field of the iron core strengthens the magnetic field of the coil.

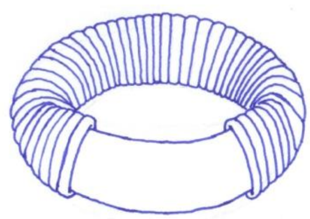
A coil with an iron core that exhibits magnetic properties only when an electric current is present is called an electromagnet. An ordinary nail can also be turned into an electromagnet. If we wind a wire around a nail and connect it to a battery, we have an electromagnet. The nail is a magnet as long as the connection to the battery works. As soon as the connection to the battery is lost, the magnetic properties of the nail also cease.

If you change the current in the coil, the magnetic field of the electromagnet will also change. The greater the current in the coil, the stronger the magnetic field of the electromagnet. The strength of the magnetic field also depends on the number of turns in the coil winding. The more turns of wire in the coil, the stronger the magnetic field of the electromagnet. If a higher than permitted current occurs, the electromagnetic circuit breaker interrupts the electric current in the circuit. An electromagnet only works in a circuit. When the electric current is turned off, the magnetic field of the electromagnet disappears. An electromagnet has several advantages over a permanent magnet. The strength and direction of an electromagnet's magnetic field can be changed by changing the strength and direction of the current.

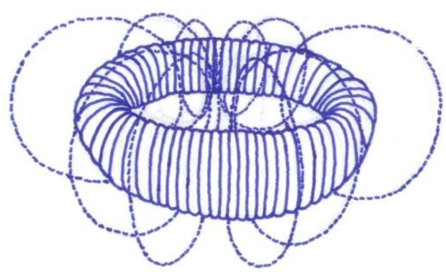
A coil with an iron core has a greater effect on iron objects compared to a coil without an iron core. This is due to the fact that the iron core in the magnetic field of the current-carrying coil is magnetized, or becomes a magnet. Consequently, the magnetic field of the iron core strengthens the magnetic field of the coil. But when the iron core moves, the magnetic field of the coil changes because when the magnet moves, its field changes.

For example, a stationary permanent magnet creates a magnetic field in space, but when this magnet moves, the field changes, resulting in a solenoidal electric field. This means that a change in electric field creates a magnetic field, but a change in magnetic field creates a solenoidal electric field, which is not a "normal" electric field. A "normal" electric field is a potential field. The lines of force of the eddy electric field and the magnetic field are both closed curves, so it is difficult to distinguish them visually. That is why above and in the future we talk more about the magnetic field than the solenoidal electric field.

Exactly the same applies in case of the field of a toroid. For example, when an electric current passes through the rings of a toroid, a magnetic field is created. However, if the circular core inside the toroid (in this case a ring-shaped metal tube) starts to move or rotate during the presence of an electric current:



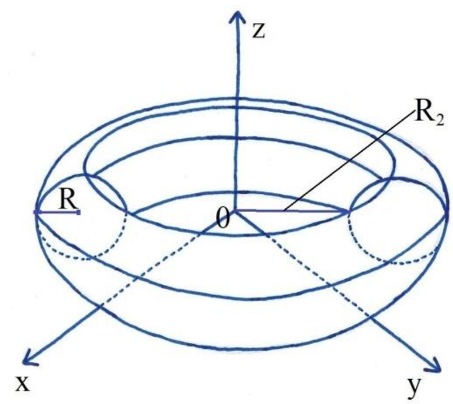
then the magnetic field of the toroid changes, resulting in a solenoidal electric field. The lines of force of the toroidal solenoidal electric field would be seen in the following figure:



The generation of the magnetic field of the toroid, which is caused by the flow of electric current in the coils of the toroid, can be described by the above definition of the magnetic flux Φ. For example, if a magnetic field is generated in the toroid, the equation for magnetic flux describes the magnetic flux inside the toroid:

$$\Phi = BS$$

in which case the magnetic field lines pass through an imaginary surface with radius R. Figure:



The external magnetic field would also be described by the equation for magnetic flux, but in this case the lines of force of the magnetic field pass through an imaginary surface with radius R_2. Both imaginary surfaces S are circular. But in both cases, the rate of change of the magnetic flux cannot

$$\frac{\Phi}{t} = \frac{BS}{t}$$

contain a quantity equal to the speed of light c. For example, the physical dimensions of a toroid do not change over time, and the change in magnetic induction B depends on the electric current flowing in the toroid's coils, which certainly does not move at the speed of light c. This applies to non-rotation of the toroid tube. However, when the toroid tube rotates, the magnetic field changes everywhere at the same time, i.e. in the entire volume covered by the toroid at the same time, and at the speed of light c. In this case, we can use the expression derived from the equation for magnetic flux:

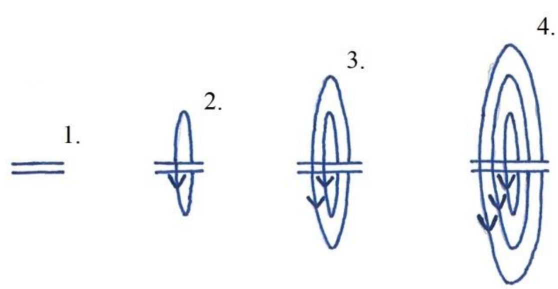
$$\frac{\tilde{\Phi}}{t} = \frac{BS}{t}$$

which contains a quantity that varies at the speed of light. The changing quantity is the area S, not the magnetic induction B. It is no longer the rate of change of the magnetic flux, but this equation describes the rate of change of the field itself.

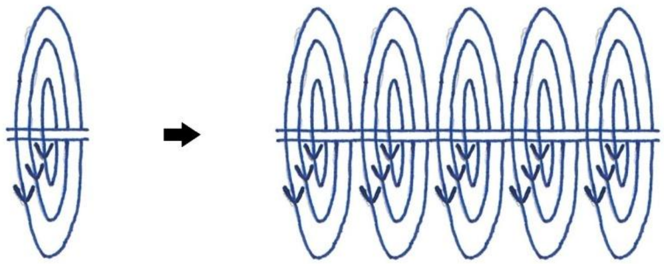
However, it should be noted here that in the latter equation

$$\frac{\tilde{\Phi}}{t} = \frac{BS}{t}$$

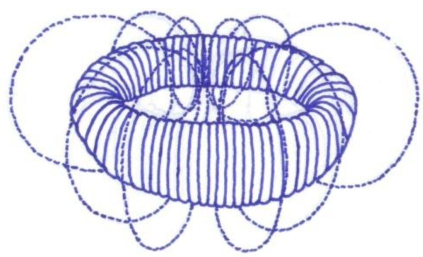
there is a circular area S due to the flat shape of the magnetic field, since the lines of force of the magnetic field generated in time and space are closed curves. Figure:



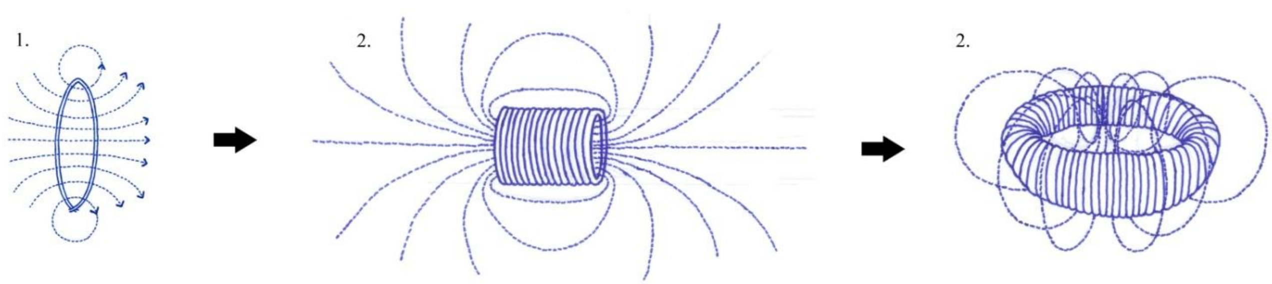
However, in case of a toroidal magnetic field, the field changes everywhere at the same time due to the rotation of the tube in the toroid, so we can add the lines of force of the magnetic field together, that is, we can only consider the resultant magnetic field, not a single magnetic field. Figure:



This means that the external magnetic field of the toroid "consists" of individual lines of force of circular magnetic fields, which have joined together to form a single field. Figure:



When an electric current passes through the toroid circles, the magnetic fields of all individual turns/circles (1) combine into a single "resultant (magnetic) field" (2). Figure:



As a result, the external uniform magnetic field, or the external resultant magnetic field, forms a ring- or loop-shaped volume $V = 2\pi^2 R r^2$, the area S of which is called "torus" in mathematics. In this case, it is no longer necessary to take into account the individual circular area S, but rather the surface area S of the torus, due to the joining of the fields

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

in which the occurring radius r manifests as:

$$r = \sqrt{\left(\sqrt{x^2 + y^2} - R\right)^2 + z^2}$$

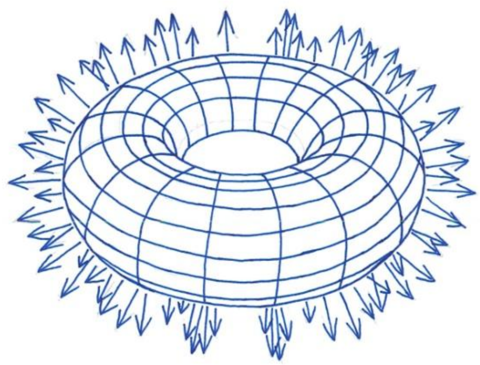
This means that in the expression derived from the equation for the rate of change of the magnetic flux:

$$\frac{\widetilde{\Phi}}{t} = B\frac{S}{t}$$

there is an area S that describes the variation of the area of a single circular magnetic field with time. However, such an equation:

$$\frac{S}{t} = \frac{4\pi^2 Rr}{t}$$

describes the change of the ring-shaped area, i.e. the area of the torus, over time. Due to the change in the resultant magnetic field of the toroid, the volume of the toroid and thus its area increases in time and space exactly at the speed of light c. It must be noted that it is not a physical surface in our understanding, but it is due to the change of the energy field spreading in space-time, which creates an imaginary temporary boundary between the older and newer fields. This imaginary boundary in time and space can be treated as a surface:



Due to moving or increasing at the speed of light, time (and actually space) on its "surface" has been transformed to infinity:

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

This is similar to the infinite transformation of time (and space) that occurs, for example, at the Schwarzschild surface at the centre of a black hole's gravitational field. Figure:

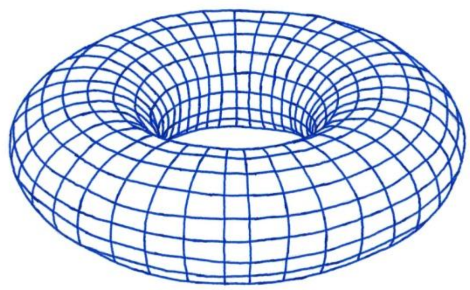
Its size is determined by the equation for the Schwarzschild radius R:

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

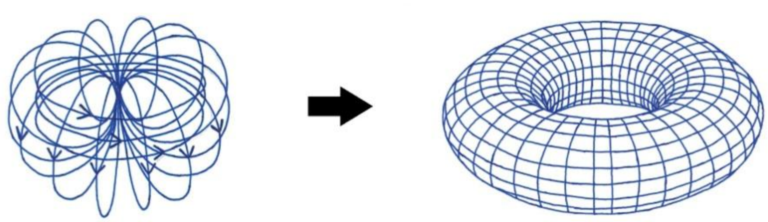
The Schwarzschild surface of a black hole is also called the trapped surface in spacetime, because the interval of spacetime is exactly equal to zero on the Schwarzschild surface of a black hole:

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

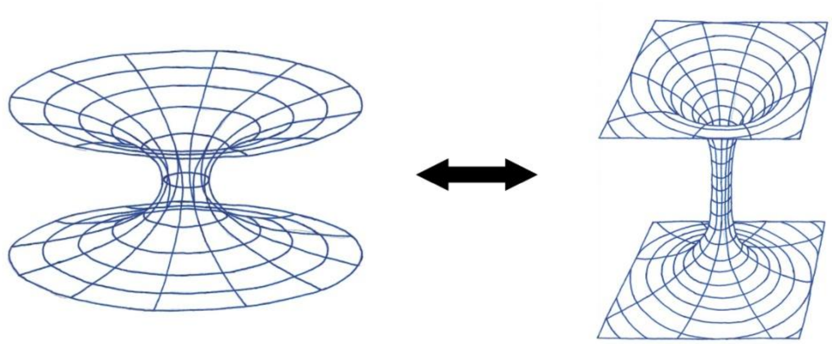
It follows from all this that due to the short-term existence of the electromagnetic field surrounding the toroid, the toroid is also briefly surrounded by a "trapped surface in spacetime", which in this case is ring-shaped or loop-shaped. Figure:



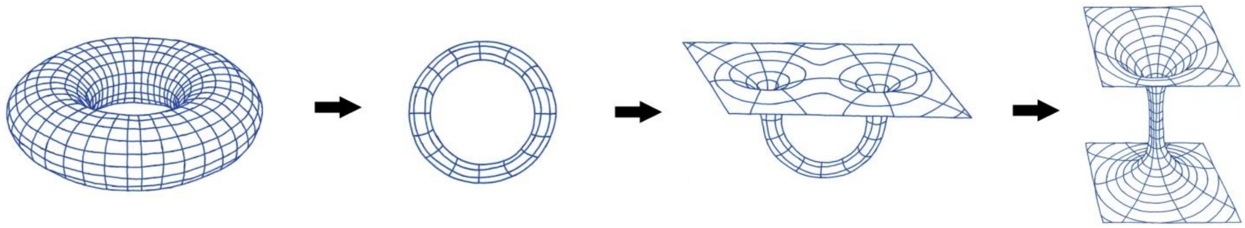
The closed lines of force of the magnetic field form a donut-shaped energy field around the toroid, which also determines the geometric shape of the trapped surface in spacetime. Figure:

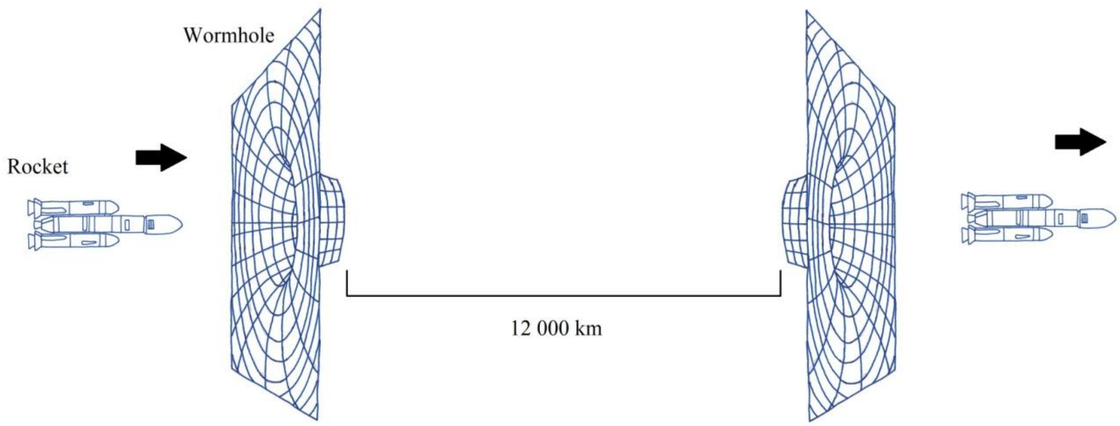


The space-time trap surface is a part of the tunnel in spacetime or wormhole. In many physical models, a wormhole is presented as a tunnel through spacetime. In most physical models, the wormhole is presented quite similarly, figure:



The drawings clearly show how a tunnel in spacetime is obtained, which is ring-shaped. The following figure shows the physical nature of a ring-shaped tunnel in spacetime through "visual derivation":

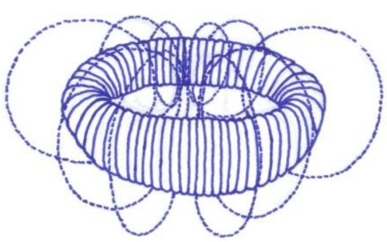




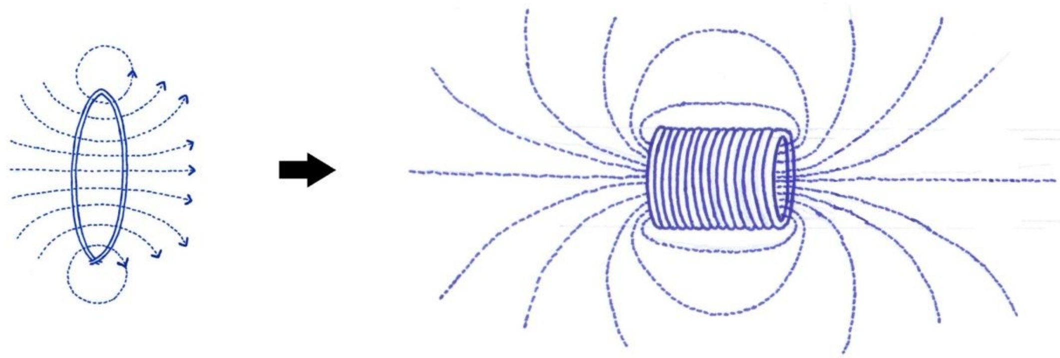
It should be noted here that the scales of the various drawings are not exact. For example, tunnels in spacetime may have different sizes or thicknesses in different drawings. However, the accuracy of the scale of the drawings is not really important here, it is important to convey the principle of physical understanding.

2.7.4 The internal field of the toroid

When an electric current passes through the toroid circles, the toroid has two magnetic fields due to its peculiar geometric shape. These are the external magnetic field:



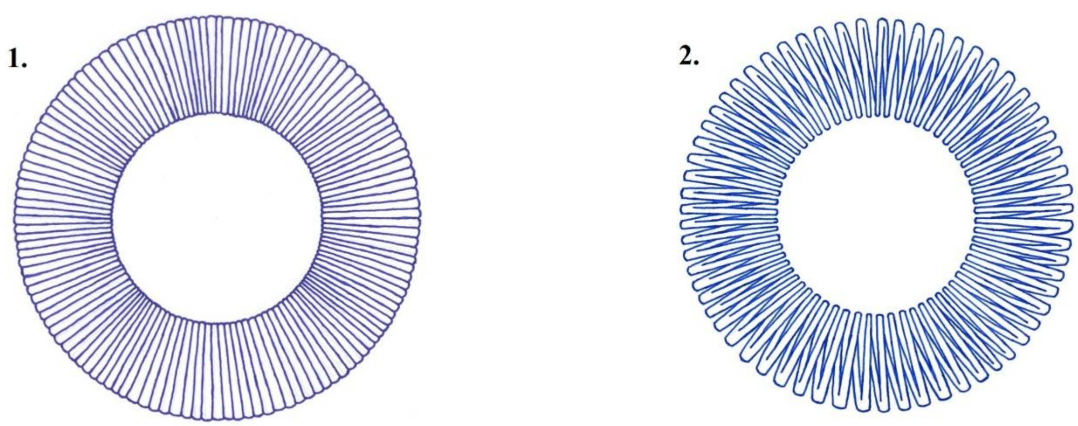
and the internal magnetic field:



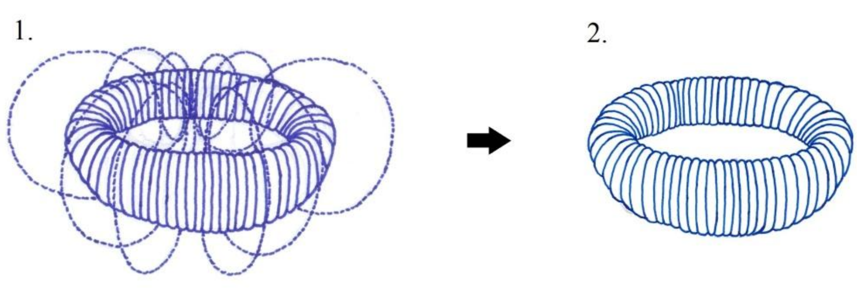
Outside the toroid, the number of ampere-turns is zero, so B is also equal to zero:

$$B * 2\pi r = 4\pi k_2 * 0$$

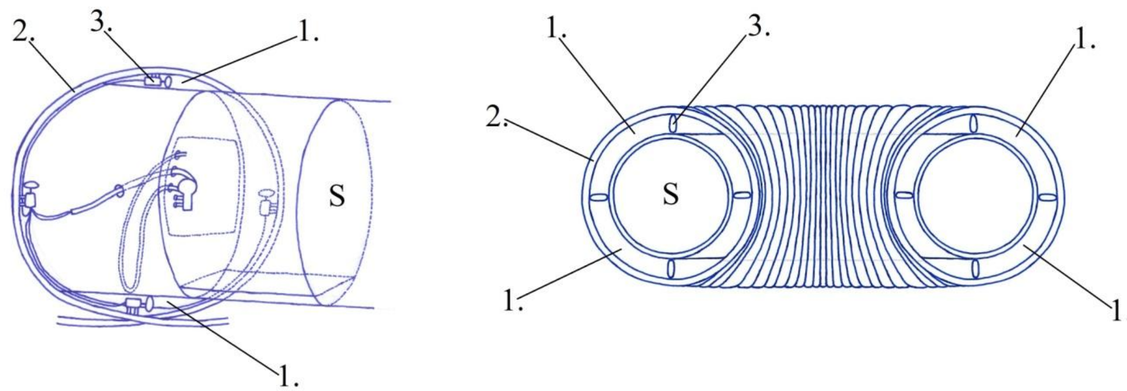
that is, $B = 0$. This means that the magnetic field is located only inside the toroid turns. However, more specifically it should be noted that in case of a densely wound toroid, the magnetic field is located only inside the toroid turns, but in case of a more sparsely wound toroid, the magnetic field is also slightly outside the toroid turns. In case of a tightly wound toroid (marked with the number 1 in the figure), there is no air gap between the turns. In case of a more thinly wound toroid (marked with number 2 in the figure), there may be air gaps between the turns. This is the essential difference. Figure:



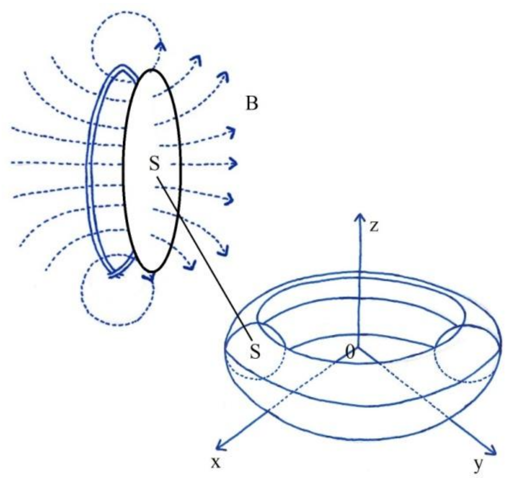
In the context of the present work, it is sufficient for the magnetic field to be present a little outside the toroid turns (2), which is hardly visible. On the figures, the magnitude of the magnetic field generated outside the toroid turns is clearly exaggerated (1). Figure:



Since the tube inside the toroid (with cross-sectional area S) is also made of conductive material (for example metal), the magnetic field is not generated inside the tube, but it is generated in the space (1) between the toroid and the tube, where the toroid wheels (3) are located. Therefore, a person is well-protected from external fields. The metal tube also shields the machine and control room of the toroid, where the electromechanical components are located, from the fields. Figure:



In case of internal magnetic field of the toroid, the lines of force of magnetic induction B run along the circular tube. Figure:



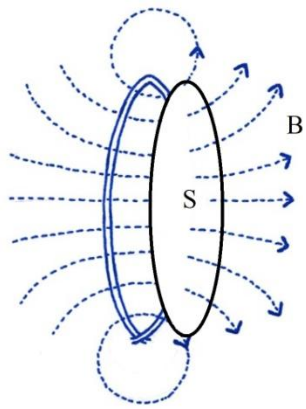
Therefore, the internal magnetic field can be described by the definition of the magnetic flux Φ:

$$\Phi = BS$$

and consequently also with the rate of change of the magnetic flux:

$$\frac{\Phi}{t} = \frac{BS}{t}$$

In these equations, the surface area S is an imaginary surface traversed by the magnetic field lines. Its imaginary surface is formed by the circle of the toroid shown in the following figure:



Definition of magnetic flux

$$\Phi = BS$$

can be used only if the electric current I flows in the toroid circle:

$$I = \frac{q}{t}$$

An electric current creates a magnetic field, the lines of force of which pass through an imaginary surface area S. However, the rate of change of the magnetic flux

$$\frac{\Phi}{t} = \frac{BS}{t}$$

can only be used if there is an electric current flowing in the toroid circle, the strength of which changes over time or which is just starting to flow in the circle.

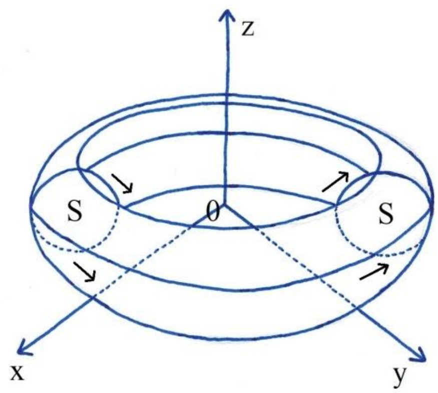
> If the electric current is just beginning to flow in a circle, then in this case the magnetic induction B changes and the imaginary surface S is unchanged, because the lines of force of the magnetic field B passing through the surface S are increasing more and more in time and space. The more lines of force there are in space, the greater the magnetic induction of the field B. However, in fact we can also consider the area S as a "variable size", since the area S traversed by the lines of force B becomes larger and larger in time and space until it reaches its maximum size, i.e. the imaginary surface area S of a circle.

From these two facts, we can draw the following conclusions about the internal magnetic field of the toroid:

1. The creation of any energy field and its propagation in space occurs at the speed of light c, but electric current cannot flow at the speed c. Electric current is the directed movement of charges with static mass in space, the speeds of which cannot in any case be equal to the speed of light c. Therefore, it can be concluded that the magnetic field is not created around the circle all at once, but the magnetic field is created around the circle at the speed of light c, because the speed of propagation of the change of the field in space (along the circle) is much higher than the speed of the electric current in the circle. But due to the change of the field, the charges start to move.

2. Since the change of the field propagates in a circle (along the circle) at the speed of light c and due to the changing field the charges start to move (the speeds of which are not

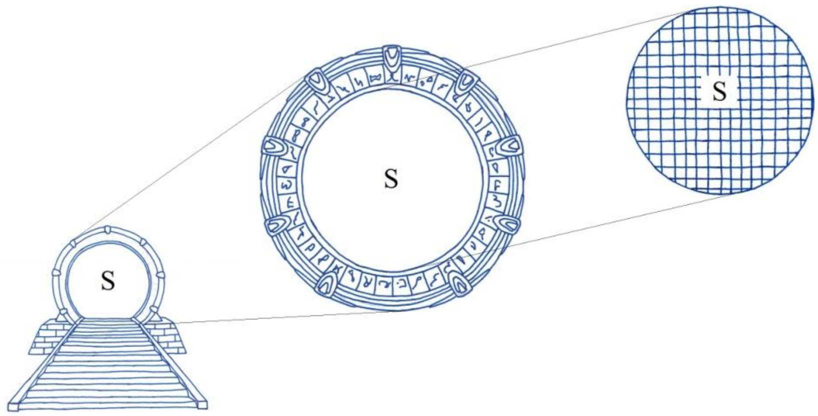
equal to the speed of light c), so the imaginary surface S can also "move" at the speed c along the circular toroidal tube. The "movement" of the surface S refers to the imaginary movement of an imaginary circular surface along a circular tube. Since an electric current flows in a circle and there are many of these circles in a toroid, the surface of the circle through which the field lines pass can be viewed as movement/propagation along a circular tube. This is the case when the electric current is just starting to flow in the toroid. Figure:



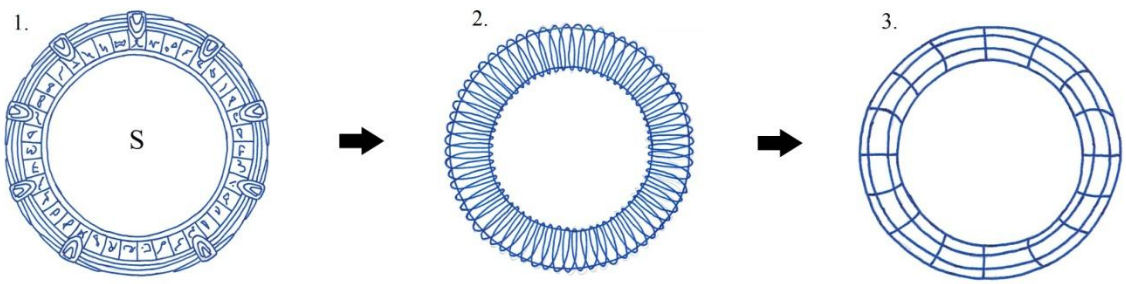
When we talk about the speed of propagation of an electric current in a conductor, we mean the speed of propagation of the electric field along the conductor, which is equal to the speed of light c. However, this does not mean that the movement of charge carriers in the conductor takes place at such an immense speed. The movement of charge carriers (for example, free electrons of a conductor) is always quite slow, with a directional drift speed of several millimetres per second, because electric charges, colliding with the atoms of matter, more or less overcome the resistance to their movement in the electric field.

2.7.5 3D graphical representation of an annular tunnel in spacetime

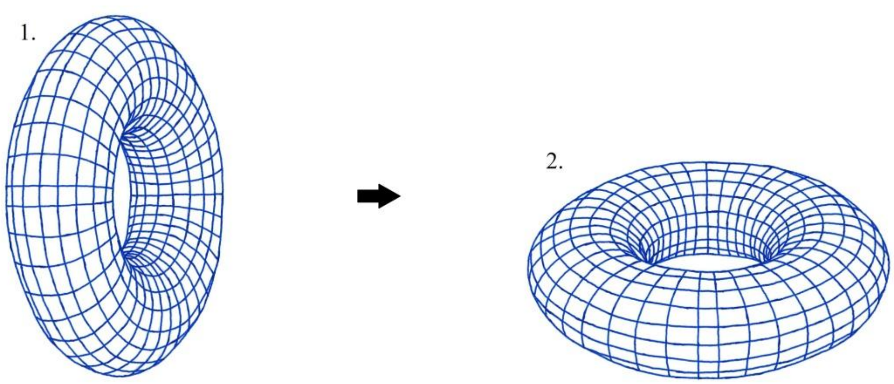
A large number of fantasy and science fiction movies depict "star gates", through which a person enters another time or space when passing through the area S. A stargate can be graphically represented as the following figure showing the area S:



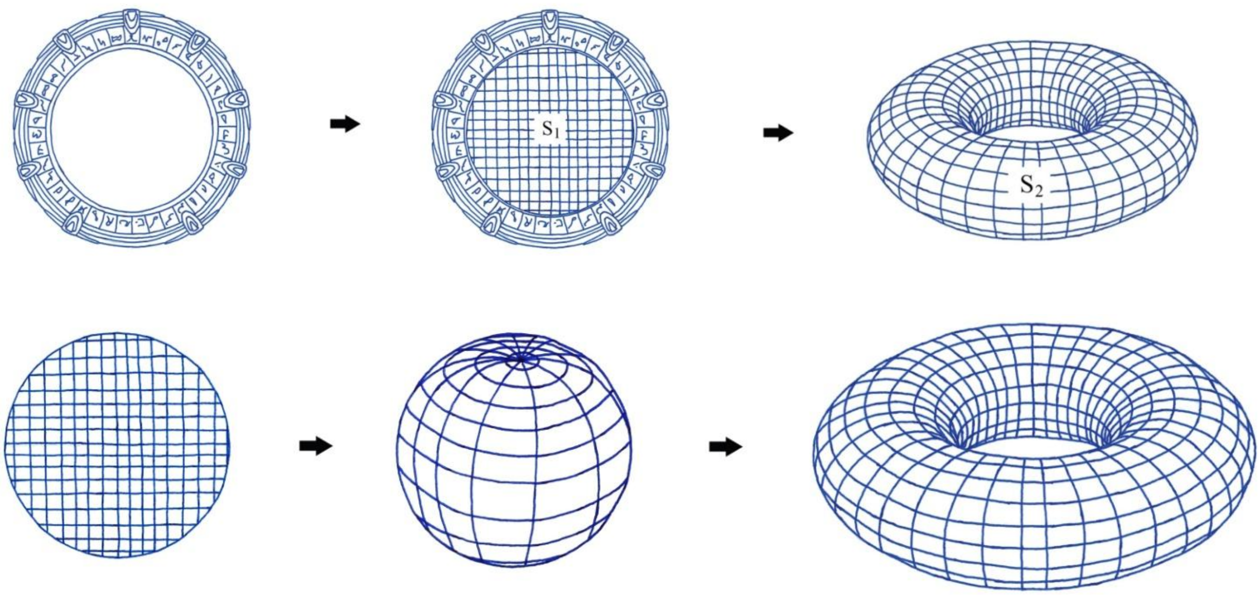
In this case, surface S allows teleportation to any time or space if a person were to pass through it. Such a possibility remains within the boundaries of fantasy and science fiction films, but it is worth noting that the loop-shaped tunnel in spacetime described in this work has similarities with the stargates depicted in science fiction films. For example, if in the case of a star gate (1) the emerging energy surface S, passing through which allows a person to get into any time or space in the universe in an instant, is important, then in this work it is the circle itself (2) that is important, not the emerging energy surface S. Around the circle (2), a loop-shaped tunnel in spacetime (3) is created, which also allows teleporting to any time or space in the universe, similarly to stargate (1). Figure:



Stargates are depicted in a generally vertical position. However, the loop-shaped tunnel in spacetime cannot be in a vertical position (1), but in the context of this work, it occurs in a horizontal position (2). Figure:

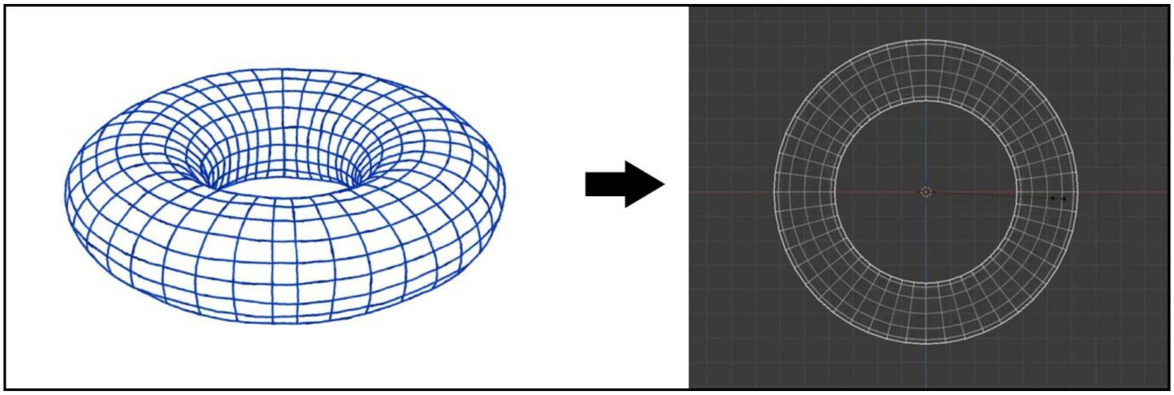


A loop-shaped tunnel in spacetime is a loop-shaped closed trapped surface in spacetime (S_2). For example, the trapped surface in spacetime that exists at the center of a black hole is also closed, not open. However, we saw above that it is also possible to "derive" another way of interpretation from the closed trapped surface in spacetime, which consisted in the following. For example, if the emerging trapped surface in spacetime is open and some kind of physical body passes through such a trapped surface in spacetime (similarly to passing through the stargate seen in science fiction movies), then you get into another time and space dimensions. In this case, the trapped surface in spacetime (which is open) can be like a gate or a window (S_1), through which one enters another time and space from both sides. While a closed trapped surface in spacetime (for example, in case of a sphere or a torus) is interpreted in physics as entrances and exits of tunnels in spacetime, an open trapped surface can be interpreted as a gate or window, through which one enters another time and space from both sides. Figure:



For example, in case of an electric field, the resulting open trapped surface in spacetime "cuts" the lines of force of the previously existing electric field. In this case, the lines of force of the electric field pass through the trapped surface in spacetime. Visually, it is similar to a situation that when a metal plate is placed in a homogeneous electric field, the lines of force of the electric field pass through the surface of the metal plate, i.e. the metal plate cuts the lines of force of the electric field. The metal plate has some thickness and it is perpendicular to the electric field.

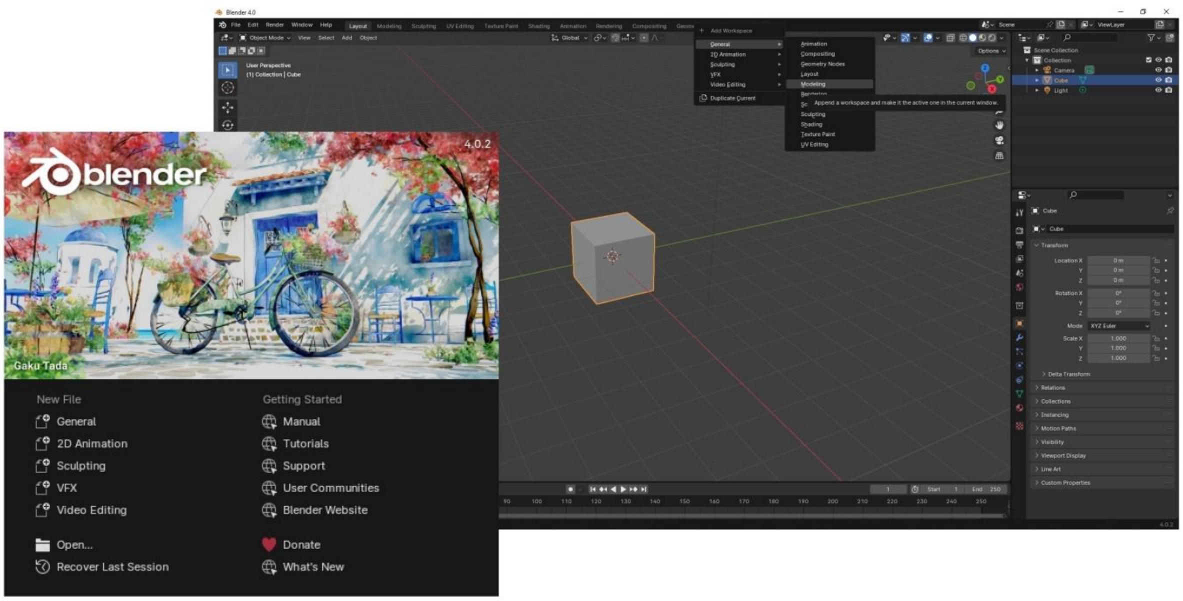
The annular tunnel in spacetime has been visualized in a computer program called Blender. Figure:

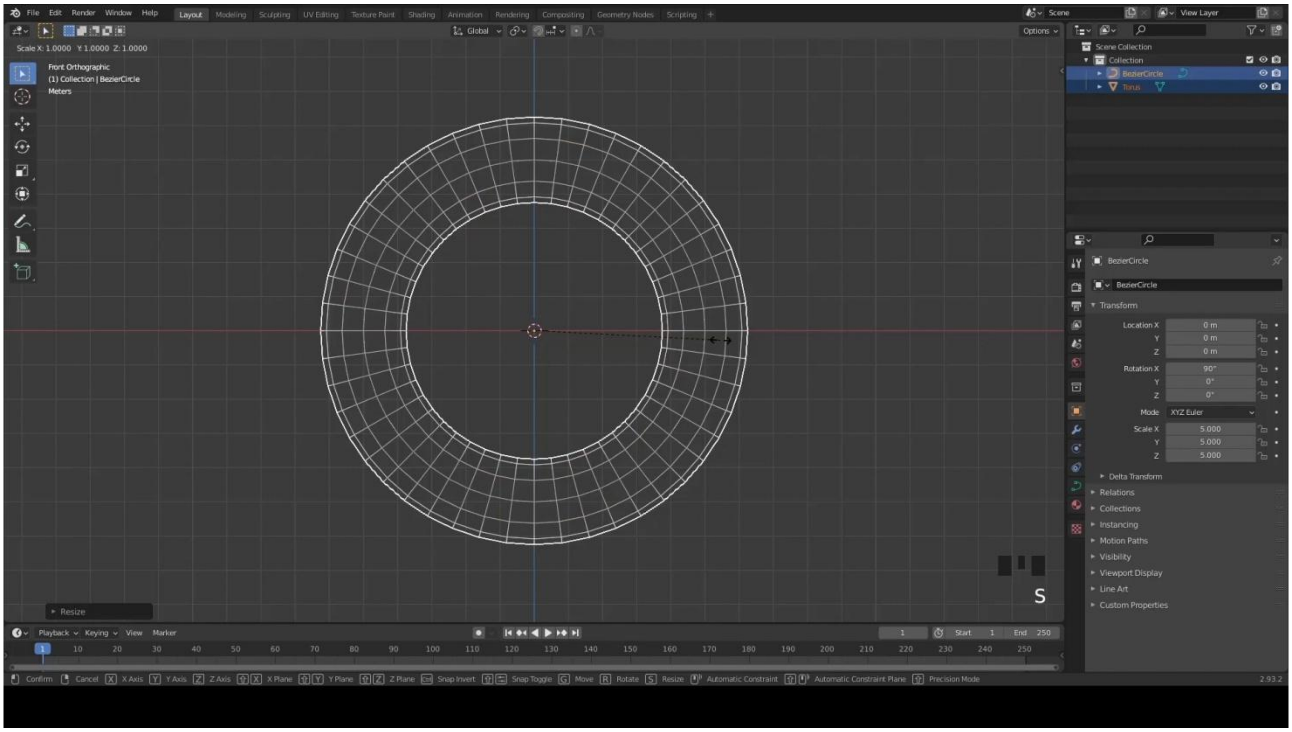


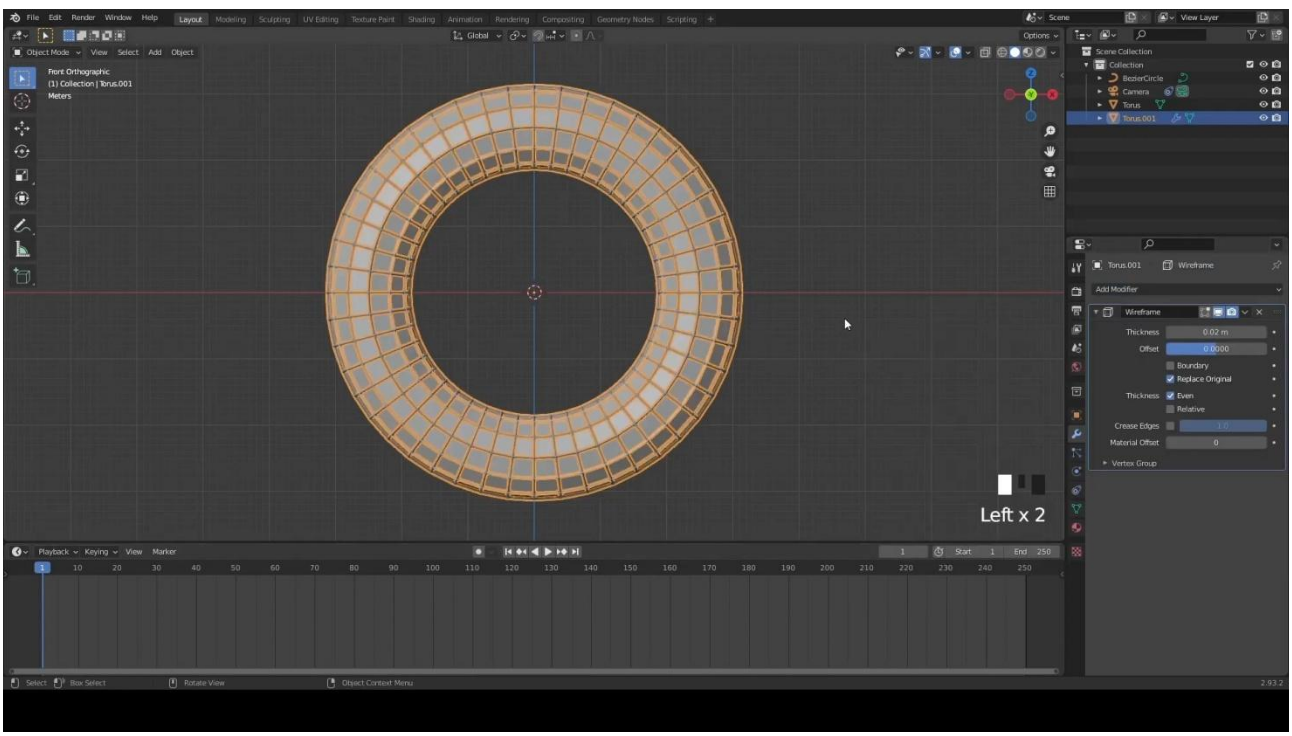
Blender is a computer program that can be used to create animated three-dimensional (or 3D) objects and environments. A computer program called 3D Blender can be downloaded and used for free at the Internet address: https://www.blender.org/. A three-dimensionally visualized, or animated, annular tunnel in spacetime creation video can be viewed and followed on the YouTube website (5):

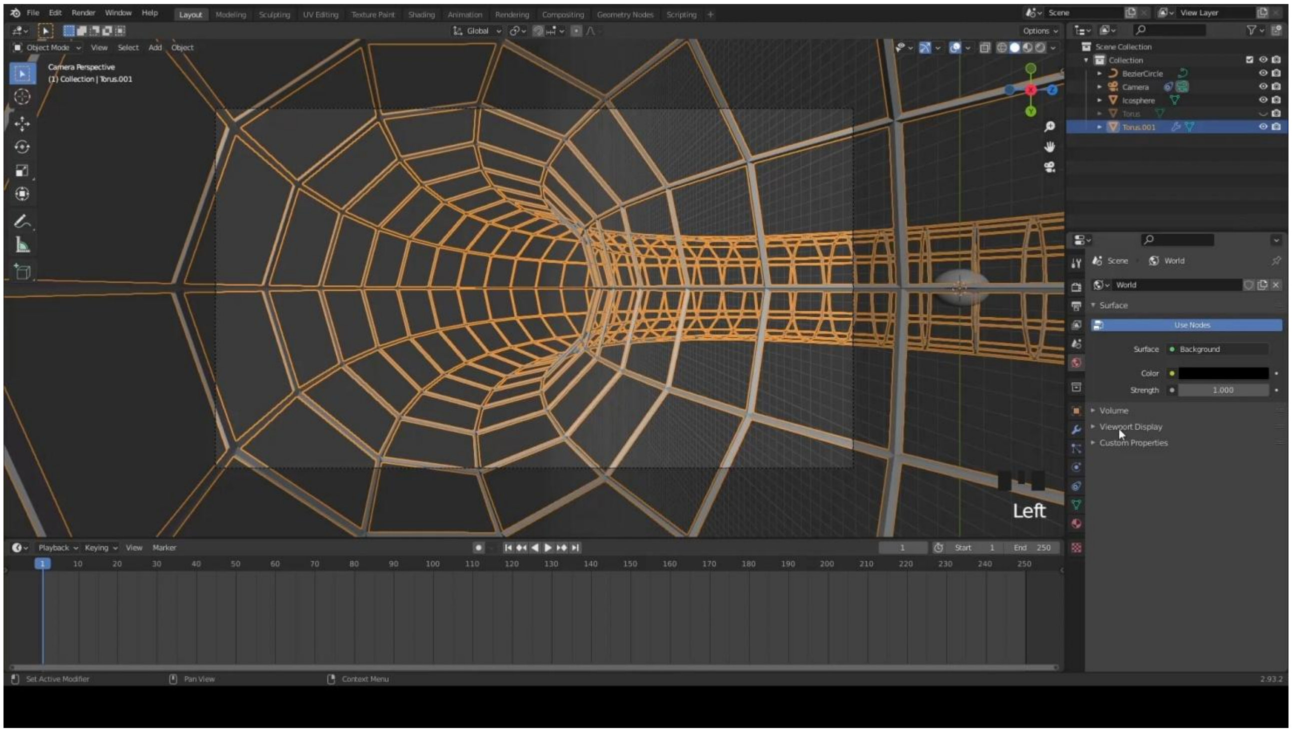
https://www.youtube.com/watch?v=t4ZydfuOsis

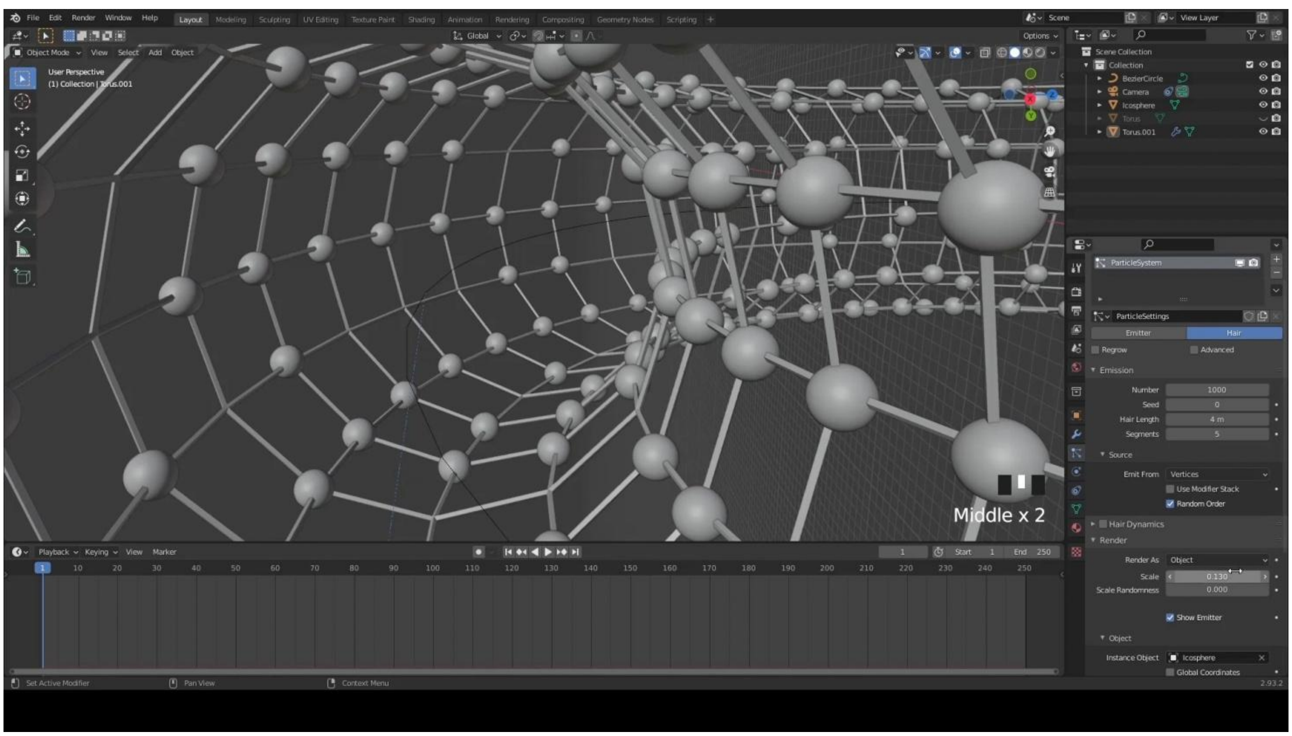
Below is a whole series of screenshots (pictures) from the previously mentioned educational video:

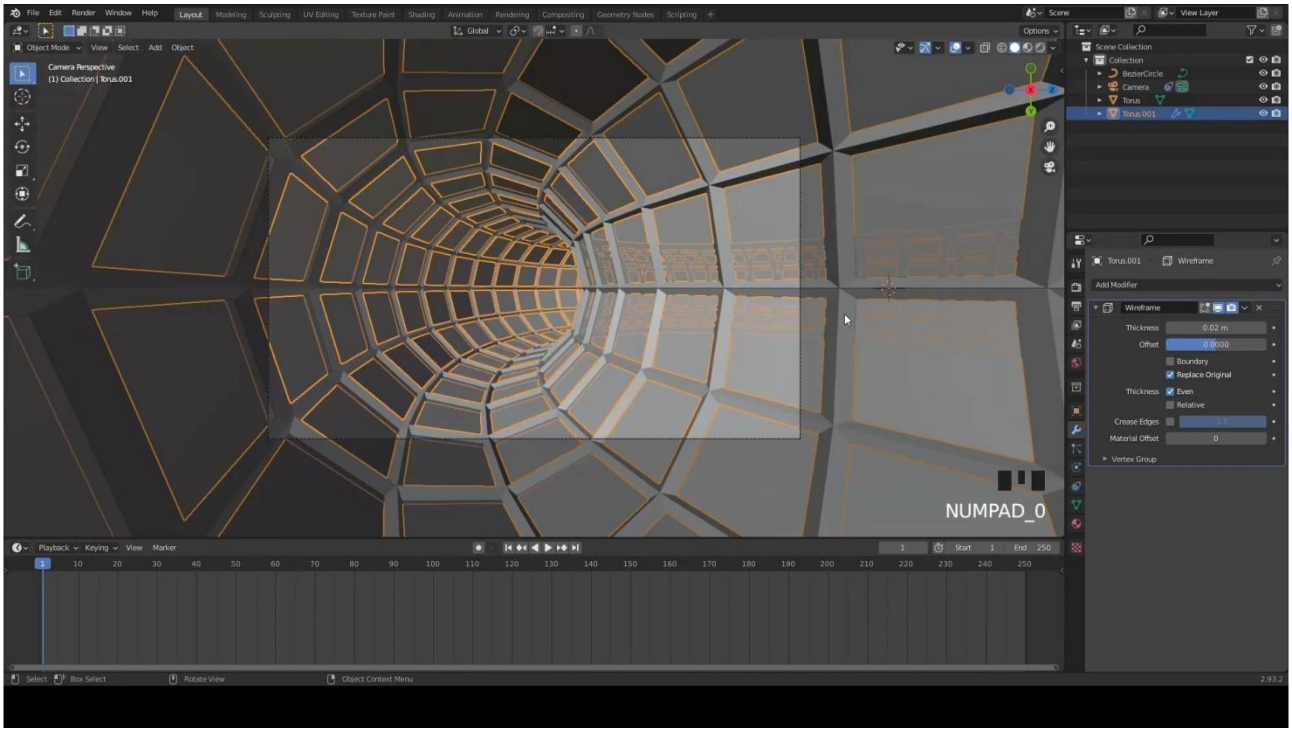


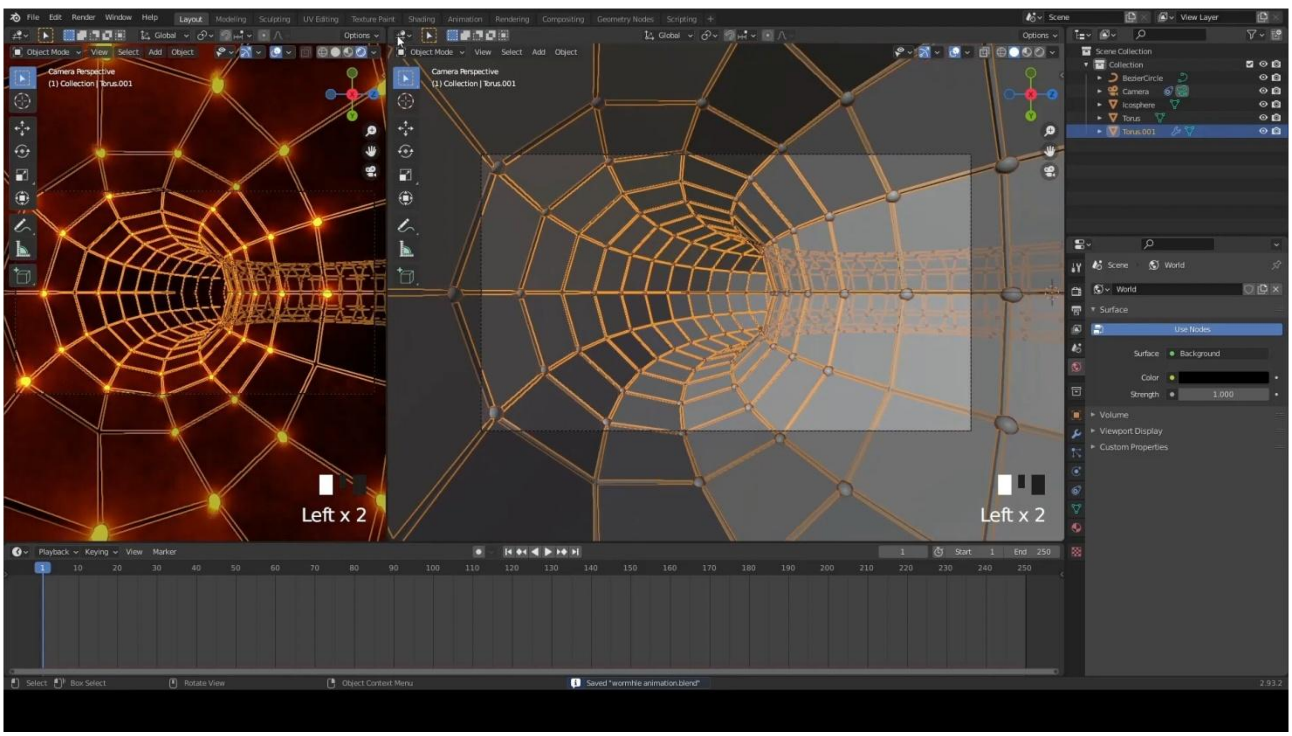

S

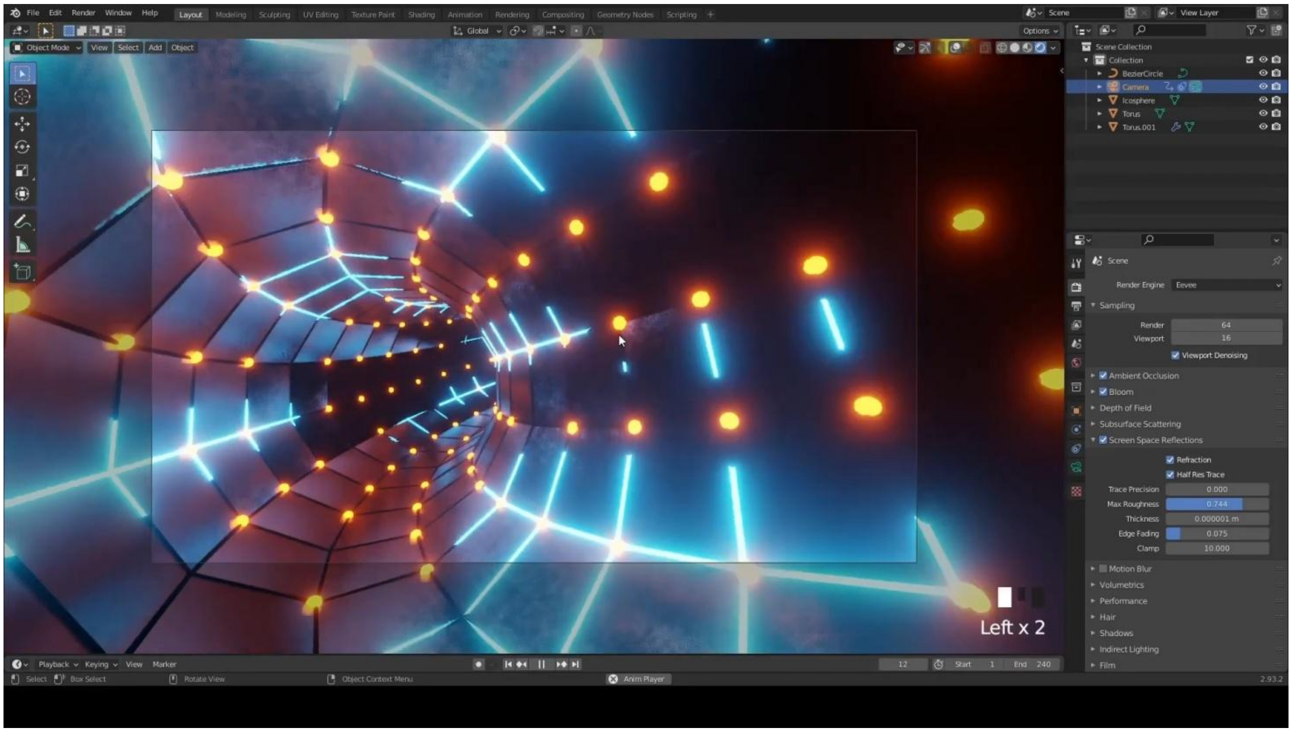

Left x 2


Camera Perspective
(1) Collection | Torus.001
Left


User Perspective
Middle x 2


NUMPAD_0


Left x 2
Left x 2


File
Edit
Render
Window
Help
Layout
Modeling
Sculpting
UV Editing
Texture Paint
Shading
Animation
Rendering
Compositing
Geometry Nodes
Scripting
Scene
View Layer
Object Mode
View
Select
Add
Object
Global
Options
Scene Collection
Collection
BezierCircle
Camera
Icosphere
Torus
Torus.001
Scene
Render Engine
Eevee
Sampling
Render
64
Viewport
16
Viewport Denoising
Ambient Occlusion
Bloom
Depth of Field
Subsurface Scattering
Screen Space Reflections
Refraction
Half Res Trace
Trace Precision
0.000
Max Roughness
0.744
Thickness
0.000001 m
Edge Fading
0.075
Clamp
10.000
Motion Blur
Volumetrics
Performance
Hair
Shadows
Indirect Lighting
Film
Left x 2
Playback
Keying
View
Marker
12
Start
1
End
240
Select
Box Select
Rotate View
Object Context Menu
Anim Player
2.93.2

WEBSITE:

www.technologyandscience.eu

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.

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. Company logo:

The limited company is non-profit working on developing technology and science in the field of wormholes. 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

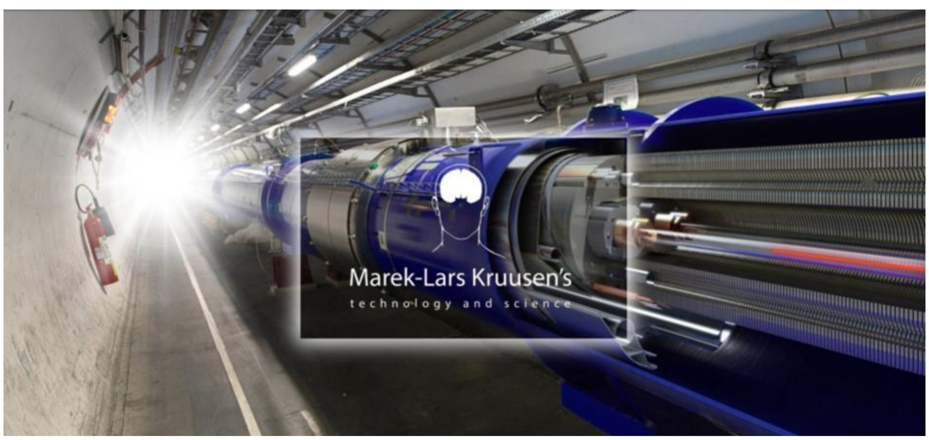
Area of activity: scientific research and development, research and experimental development on natural sciences and engineering, other research and experimental development on natural sciences and engineering. The company is registered in the Republic of Estonia (EE), which is a member state of the European Union (EU).

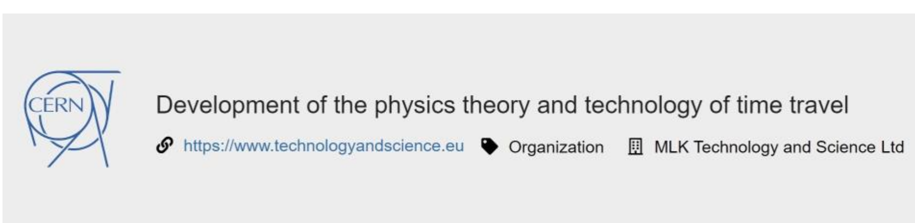
The company is also registered in the United States of America (USA):

> NAICS Codes: 611110, 611210, 611310, 611410, 611430, 813410, 813910, 813920. Cage Code: 0160J. UEI Number: JK29PY813VN7. Business Name: MLK Technology and Science Ltd. Applicable Business Names: MLK Technology and Science OÜ, MLK Technology and Science.

Marek-Lars Kruusen (MLK Technology and Science) collaborates with the Open Science Framework. This collaboration involves the publication of scientific papers and preprints on a platform managed by Open Science Framework. For example, preprints can be found on OSF, which is hosted at Center for Open Science. Open Science Framework (OSF), logo:

The company "*MLK Technology and Science*" is the founder and moderator of the research department located at CERN: "*Development of the physics theory and technology of time travel*". The European Organization for Nuclear Research, known as CERN, is an intergovernmental organization that operates the largest particle physics laboratory in the world. Established in 1954, it is based in a suburb of Geneva, on the France–Switzerland border. It comprises 23 member states. Israel, admitted in 2013, is the only non-European full member. CERN is an official United Nations General Assembly observer.





See more here: https://zenodo.org/communities/time_travel/

I have studied higher physics and mathematics at Tallinn University, which is located in the Republic of Estonia. I have acquired knowledge concerning information technology at Tallinn Polytechnic School and mechatronics and robotics at Tallinn Industrial Education Center. Studies concerning physics and mathematics have been carried out for approximately 17 years, the last 7 of which have been especially fast and fruitful. All the information is available on a webpage I created (homepage):

Company homepage: https://www.technologyandscience.eu

All the work and articles that I have ever published have been presented there. Some of the information is presented in Estonian and some of the information is presented in English. A lot of translating has to be done from Estonian to English.

References

1. United States Patent and Trademark Office (USPTO, website: https://www.uspto.gov). The corresponding patent applications by Marek-Lars Kruusen have been filed in 2023. Patent application number is: 18/339,426; and title of invention: „*Method and equipment for creating a tunnel in spacetime or wormhole*".

2. Marek-Lars Kruusen, „*Ajas rändamine ja selle tehnoloogilised alused*" (in english: „*Time travel and its technological foundations*"), National Library of Estonia: https://www.digar.ee/arhiiv/en/nlib-digar:667381. Zenodo (European Organization for Nuclear Research, CERN): https://doi.org/10.5281/zenodo.10813949.

3. Magazine „*Imeline teadus*" (in english: „*Wonderful Science*"), no. 10/2014, page 88-95, Tallinn, Estonia.

4. Energy consumption, comparison, YouTube: https://www.youtube.com/watch?v=5Dh6GHcn508

5. 3D Wormhole in Blender, YouTube video: https://www.youtube.com/watch?v=t4ZydfuOsis

6. The image on the front cover (Albert Einstein, in the first version) is taken from Wikipedia.

Photograph by Orren Jack Turner, Princeton, N.J. Modified with Photoshop by PM_Poon and later by Dantadd. This image is available from the United States Library of Congress's Prints and Photographs division under the digital ID cph.3b46036. Created: copyrighted 1947, copyright not renewed. Einstein's estate may still claim copyright on this image, but any such claim would be considered illegitimate by the Library of Congress. No known restrictions.

Marek-Lars Kruusen's

technology and science