

# About the mass

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## Abstract

Using the mass model, the article examines the thesis about the fundamental nature of the field form of matter in physics. A field model of inert and heavy mass is constructed and on this basis the mechanism of inertia and gravity of massive bodies is revealed. The mass model is compared with the Dirac equation.

## 1 About the mass

### 1.1 Field model of inert and heavy mass

Consider a thought experiment.

Let the reference frame  $K'$  contain a weightless cylinder of height  $h$  (Fig.1). We

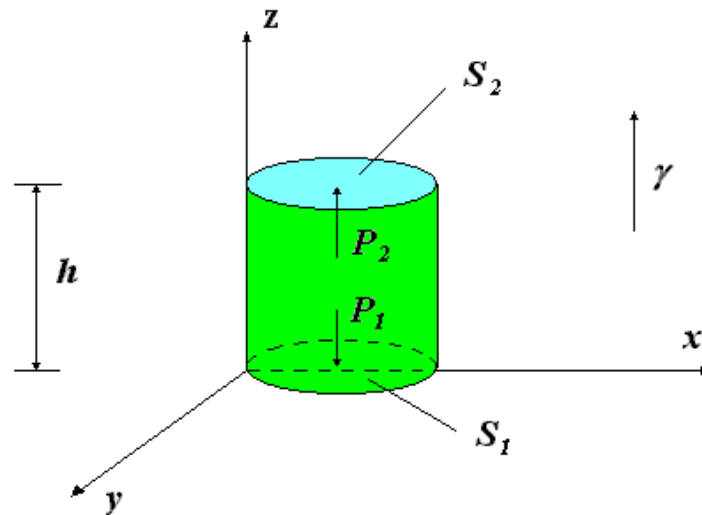


Figure 1: Model of mass

denote the upper cylinder cover by  $S_2$ , the lower one by  $S_1$ . Let this frame of reference

$K'$ , together with a weightless cylinder rigidly fixed to it, move in the direction of positive values of  $z$  with the acceleration  $\gamma$ . Suppose that a photon with energy  $E_0$  is emitted from  $S_2$  in  $S_1$  and we consider this process in some system  $K^0$ , which does not have acceleration. Suppose that at the moment when the radiation energy is transferred from  $S_2$  to  $S_1$ , the system  $K'$  has a speed equal to zero relative to the system  $K^0$ . The light quantum will reach  $S_1$  after the time  $h/c$  (in the first approximation), where  $c$  is the speed of light. At this moment,  $S_1$  has a velocity  $\gamma h/c = v$  relative to the system  $K^0$ . Therefore, according to the special of relativity, the radiation reaching  $S_1$  does not have the energy  $E_0$ , but has a large energy  $E_1$ , which is in first approximation related to  $E_0$  by the relation [1]

$$E_1 \approx E_0 (1 + v/c) = E_0 (1 + \gamma h/c^2) \quad (1.1)$$

The momentum transmitted by the radiation to the wall  $S_1$  is equal to

$$P_1 = E_1/c = E_0 (1 + \gamma h/c^2)/c \quad (1.2)$$

Let a light quantum with the same energy  $E_0$  be emitted from  $S_1$  toward  $S_2$ . Then the radiation energy reaching the wall  $S_2$  and the transmitted momentum will have the following form

$$E_2 \approx E_0 (1 - v/c) = E_0 (1 - \gamma h/c^2) \quad (1.3)$$

$$P_2 = E_2/c = E_0 (1 - \gamma h/c^2)/c \quad (1.4)$$

If in the system  $K'$  we simultaneously emit two quanta of light of the same energy - one toward  $S_1$  and the other towards  $S_2$ , the recoil momentums are compensated, and the momentums (1.2) and (1.4) will play the main role. We get

$$\Delta P = P_1 - P_2 = (2E_0/c^2)(\gamma h/c) = 2m \Delta v \quad (1.5)$$

where  $2m = 2E_0/c^2$  is inert mass; coefficient 2 corresponds to two photons.

The equation for the force  $F$  acting for time  $\Delta t$  will have the form

$$F = \Delta P/\Delta t = 2m \Delta v/\Delta t = 2m \gamma \quad (1.6)$$

in accordance with Newton's second law.

Thus, a weightless cylinder in which radiation is located has an inertial mass  $2m$ . The momentum  $\Delta \vec{P}$  of this inertial mass, as is easily seen from Fig.1, is directed in the direction opposite to the acceleration vector  $\vec{\gamma}$ . Thus, a weightless cylinder with a cloud of photons inside the cylinder exerts resistance to its accelerating force, which is one of the characteristic manifestations of that physical property called "mass." The inertial mass characterizes the resistance exerted by the body to any change in its velocity both in magnitude and in direction. In modern physics, the phenomenon of inertia of massive material bodies is still an unsolvable riddle. As A. Pais noted: "The problem of the origin of inertia was and remains the darkest question in the theory of particles and fields".[2] The above mechanism removes the aura of mystery from the phenomenon of inertia of massive bodies.

So, a massive particle can be represented as a weightless vessel (hollow ball) with mirror walls, in which there is a cloud of massless particles. Momentums of particles

on average are uniformly transmitted to mirror walls in all directions and the vessel will be in a state of relative rest (i.e. *dynamic equilibrium*). When the vessel is accelerated, the total transferred to the vessel walls by massless particles becomes nonzero in the direction opposite to the acceleration vector. This manifests itself in the form of inertness of the vessel. When the force applied to the vessel disappears, the *dynamic equilibrium* of the vessel is restored, but the vessel acquires velocity  $v$  relative to the primary frame of reference. The inertial mass model clearly shows that the inertia of material bodies is their internal property and the Mach principle to tangible material bodies is inapplicable. Such a cylinder will have inertia in the absence of a horizon of distant stars.

In accordance with the principle of Mach, it is assumed that the gravitational field is the source of inertia of bodies in the universe. However, although the Mach principle played a definite heuristic role in the construction of the theory of relativity, there is reason to believe that in this formulation it is unacceptable. As was shown above, the bodies do not cease to possess inertial properties, even in an empty, mass-free space.

It is also clear why the huge energy reserves are "hidden" in the mass. This field energy is only partially released in nuclear fission processes in nuclear reactors, as well as in nuclear fusion processes spontaneously flowing in the Sun and other stars.

Further. Let the weightless cylinder (Fig.1) do not accelerate, but is located on a support and is in the weak gravitational field of the Earth. Suppose that in  $S_1$  the field potential is equated to zero, and at the height  $h$  it is equal to  $\varphi$ . Taking into account the equivalence principle, we can write  $\gamma h = \varphi$ . Now let a light quantum with energy  $E_0$  be emitted from  $S_2$  in  $S_1$ . Then the energy and momentum of the photon change according to the relations

$$E_1 \approx E_0 (1 + \varphi/c^2) \quad (1.7)$$

$$P_1 = E_1/c = E_0 (1 + \varphi/c^2)/c \quad (1.8)$$

On the other hand, emitting a photon of energy  $E_0$  from  $S_1$  to  $S_2$  we obtain

$$E_2 \approx E_0 (1 - \varphi/c^2) \quad (1.9)$$

$$P_2 = E_2/c = E_0 (1 - \varphi/c^2)/c \quad (1.10)$$

As a result, the difference of  $P_1$  and  $P_2$  is equal to

$$\Delta P = P_1 - P_2 = (2E_0/c^2)(\Delta\varphi/c) = 2m(\Delta\varphi/c) \quad (1.11)$$

and directed towards the center of the Earth. Here  $2m = 2E_0/c^2$  is a heavy mass. Therefore, the force acting on  $S_1$ , is

$$F_z = \Delta P/\Delta t = -2m(\Delta\varphi/c \Delta t) \quad (1.12)$$

For light in the field of the Earth vertically  $c \Delta t = \Delta z$ , then  $F_z = -2m(\Delta\varphi/\Delta z)$  or, more generally

$$F(\vec{r}) = -2m \text{grad } \varphi(\vec{r}) \quad (1.13)$$

where  $\varphi(\vec{r}) = -GM/r$ ;  $G$  is a gravitational constant;  $M$  is the mass of the Earth.

We have received expression for the force of gravity acting on the cylinder, it follows from Newton's theory of gravitation.

It follows from the mass model that the free motion of a material structure in a gravitational field (dip or motion along a geodesic) is associated with a constant redistribution of the momentums of massless energy quanta with respect to the structure of the body. Removing the stand, we force the cylinder to move under the action of the difference of the photon momentums  $\Delta P$ , as a result of which it appears in the region of the field with a larger potential difference  $\Delta\varphi'$  than at the previous time. This generates a large difference in the momenta  $\Delta P'$  and the process repeats. This is how the cylinder accelerates in the gravitational field. Thus, the field model of mass adequately reflects the inert and heavy properties of massive bodies.

## 1.2 Philosophy of Mass

The above approach interprets the general theory of relativity as a method of describing the gravitational field with the help of the concept of *curved spacetime*. Indeed, according to the modern approach, spacetime is not a thing that can be "warped". This is an abstract mathematical model of what we call ordinal and metric relations: we can measure distances and time intervals, events occur in a certain sequence, and so on. The very relationships are determined by the distribution of matter, its motion and interaction. The model of all this is *spacetime*. The results of our measurements are in better agreement with the curved spacetime than with the flat one.

Light, possessing energy, is subject to the influence of the gravitational field. This circumstance affects the law of the propagation of light, and hence, on the general laws of establishing spacetime relations. In other words, the presence of a gravitational field should exert a certain influence on the properties of spacetime, which actually takes place. The gravitational field, through the influence of the light propagating through its influence, determines the geometry of space. *The movement of the rays of light determines the spatio-temporal structure of the world.* On the other hand, the physical basis for introducing the concept of "curved spacetime" for massive bodies and their free motion along geodesic trajectories is the field model of the inert and heavy mass described above, formed by massless energy quanta. It becomes understandable the universal nature of the effect of the gravitational field on all material bodies in nature (massless and massive). It consists in the effect of the gravitational field on the character of the propagation of massless energy quanta in the free and bound states. Thus, *the basis of the observed world is the massless form of matter.*

It is obvious that a cylinder with weightless walls can be replaced by a system of two (or more) interacting massless particles. Massless particles oscillate within certain limits, repeatedly reflected from imaginary "walls", which are nothing but *a potential barrier*. A bound system of such particles will have the same inert and heavy properties as the above-discussed weightless cylinder. Here, Einstein's assumption is justified, that *matter is the concentration of field energy in a small space*. It is clear that any bodies composed of a combination of such elementary cylinders will fall with the same acceleration in the field of gravitational forces, since all cylinders are identical.

Modern physics has come to the conclusion that in the Planck scale all matter particles (both real and virtual) do not yet have masses (that is, they are all like a photon) and, therefore, the above mechanism of mass formation applies to them.

The constructed model of inert and heavy mass is a universal model, since inertness and heaviness in a substance cannot occur in various ways.

An interesting question is whether our weightless cylinder can move at a speed exceeding the speed of light? Since our cylinder is analogous to the aggregate of massless quanta of energy, connected by some kind of interaction, the question of whether it reaches a speed greater than the speed of light amounts to the following: will light be able to overtake the light? The answer is obvious - can not. The system of two coupled photons, as we have shown above, possesses inertial properties and therefore will move with a velocity less than the speed of light or will be at rest. It is clear that the speed of light for such a system will be the limiting speed. A body made up of light can not move faster than light.

From the foregoing it follows that the massless form of matter is primary, fundamental, and the massive form of matter is a secondary, derivative form.

Indeed, under conditions (at least) of the Great Unification, the processes of electromagnetic, weak and strong interactions are indistinguishable. This state has such characteristic features: 1) Particles of matter (both real and virtual) "for the time being" do not have masses (that is, they are like a photon). 2) The potential energy of particle interaction is "regulated" by special scalar Higgs fields.

The primary nature of the field can also be traced in quantum mechanics. As a result of the quantization of the field, the concept of a particle arises as a characteristic of the excitation of an electromagnetic wave with a certain length. The idea of perceiving particles as quantum states of oscillators of a certain field turned out to be fruitful. It permeates all modern theoretical physics. The field is the primary concept. Elementary particles arise as a result of its quantization.

### 1.3 Dirac equation, correspondence principle and mass model

The Dirac equation can be proved with the help of the correspondence principle. The energy and momentum of a particle can be expressed by the equation

$$E^2 = p_1^2 c^2 + p_2^2 c^2 + p_3^2 c^2 + m^2 c^4 \quad (1.14)$$

This equation can be divided into  $E$  on both sides. We obtain

$$E = \frac{v_1}{c} p_1 c + \frac{v_2}{c} p_2 c + \frac{v_3}{c} p_3 c + \frac{v_0}{c} m c^2 \quad (1.15)$$

where  $v_0 = \sqrt{c^2 - v^2}$  and  $v^2 = v_1^2 + v_2^2 + v_3^2$

Really

$$\frac{p_1 c}{E} = \frac{m v_1 c (c/v_0)}{m c^2 (c/v_0)} = \frac{v_1}{c}$$

and so on, and

$$\frac{m c^2}{E} = \frac{m c^2}{m c^2 (c/v_0)} = \frac{v_0}{c}$$

The Dirac equation has the form

$$i\hbar \frac{\partial \psi}{\partial t} = (\alpha_1 \hat{p}_1 c + \alpha_2 \hat{p}_2 c + \alpha_3 \hat{p}_3 c + \alpha_0 m c^2) \psi \quad (1.16)$$

where  $\alpha_j$  is matrix ( $j = 0, 1, 2, 3, \dots$ ). We obtain from (2.15) and (2.16):  $v_j/c \rightarrow \alpha_j$ .

In fact, in quantum mechanics it shows that the relativistic velocity operator  $v_\nu = dx_\nu/dt$ ; ( $\nu = 1, 2, 3$ ) has the form  $v_\nu = c\alpha_\nu$ , ie is a matrix operator (see [3] p.340-342).

Really

$$\frac{dx_\nu}{dt} = \frac{\partial x_\nu}{\partial t} + [H, x_\nu] \quad (1.17)$$

where

$$H = \alpha_\nu p_\nu c + \alpha_0 m c^2 \quad (1.18)$$

Since the operator  $x_\nu$  does not depend on time, it will be  $dx_\nu/dt = [H, x_\nu]$ . We get

$$\frac{dx_\nu}{dt} = [(\alpha_\mu p_\mu c + \alpha_0 m c^2), x_\nu] \quad (1.19)$$

The matrix  $\alpha_\mu$  commutes with  $x_\nu$ , so that the matrix  $\alpha_\mu$  can be factored out. Finally we have

$$dx_\nu/dt = c\alpha_\mu [p_\mu, x_\nu] = c\alpha_\mu \delta_{\mu\nu} = c\alpha_\nu \quad (1.20)$$

The eigenvalues of the matrix of the velocity operator equal to  $\pm c$ . This indicates that the basis is movement at the speed of light. But as the operator of the speed does not commute with the Hamiltonian operator, then in the experience is always measured the average value of the relativistic velocity operator, and it is less than  $c$ .

Thus, the correspondence between equations (1.15) and (1.16) is confirmed.

The Dirac equation predicts the rapid oscillatory motion of an elementary particle - "trembling motion". To understand the effect of electron trembling, it is enough to accept our conventional model of inert and heavy mass. According to this model, a massive particle is a hollow weightless cylinder (or hollow ball) with internal mirror walls and a cloud of photons inside. Let's assume that the electron is a cylinder with one photon. Reflecting from one wall, the photon transfers its momentum to the cylinder. The cylinder moves to the right at the speed of light  $c$ . Having reached the opposite wall and reflected from it, the photon also transfers its momentum to it and the cylinder moves to the left at the speed of light  $c$ . And the process repeats. As a result, a jitter of a weightless cylinder simulating a massive electron occurs. From a distance, it seems that the cylinder is at rest. The length of the cylinder is  $l = 10^{-13}m$ , the speed of light is  $c = 3 * 10^8 m/sec$ , so the jitter frequency is  $\nu \sim c/l \approx 10^{21} Hz$ . [4] Thus, in reality, an elementary particle moves with the speed of light.

## 2 Conclusion

The author's goal was to show that the field form of matter can underlie the weighty form of matter. This hypothesis allows us to explain such properties of matter as 1. its inertia and weight; 2. the inability of the heavy form of matter to reach speeds greater than the speed of light; 3. the universal nature of the influence of the gravitational field on all physical matter; 4. The possibility of mutual transformation of elementary particles into each other.

## References

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- [4] WikipediA, "Zitterbewegung"