Dynamic Weighing Experiments - the Way to New Physics of Gravitation

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Abstract. Dynamic weighing is a measuring of size of the average gravity force acting on a test body which is in the state of accelerated movement. The acceleration of a body, or its microparticles, can be caused both by forces of gravitation, and by a direct, electromagnetic in nature, influence on the part of other bodies. It is just dynamic weighing of bodies which is informative in studying the features of electromagnetic and gravitational forces interaction. The report gives a brief review of results of experiments with weighing of accelerated moving bodies – in case of shock phenomena, in state of rotation, and in heating. Special attention is given to measurements of free fall accelerations of a mechanical rotor. In majority of the laboratory experiments executed with the purpose of checking the equivalence principle, the axis of a rotor was oriented verticallly. In our experiment we measured the free fall accelerations of the closed container inside which a mechanical rotor (gyroscope) with a horizontal axis of rotation was installed. There was observed an appreciable, essentially exceeding errors of measurements increase of acceleration of free falling of the container at angular speed of rotation of a rotor up to 20 000 rev/min. The physical conditions of free vertical falling of a body essentially differ from conditions of rotary (orbital) movement of a body in the field of gravity and the result obtained by us does not contradict the results of measurements of a gyroscope precession on satellites. Experiments with dynamic weighing of bodies give useful information on complex properties of the gravity force which are beyond the scope of well-known theories. Their careful analysis will allow to expand and supplement the concepts based on the general theory of relativity, and probably to open a way to new physics of gravitation and to new principles of movement.

Keywords: Gravity Force, Weighing, Acceleration, Free Falling, Gyro, Equivalence Principle .
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INTRODUCTION

Though physics is an experimental science, in modern physics of gravitation the scale of theoretical researches has considerably surpassed the scale of experiments. In a solid, over 600 pages, recently published review «100 Years of Gravity and Accelerated Frames » the experimental (and besides - astrophysical) tests of gravitational theories are given less than 30 pages (Hsu and Fine, 2005). Attempts to establish some new properties of gravitation in laboratory experiments, from the point of view of classical GR, are usually considered as unpromising. Meanwhile, the grounds for criticism of experimental basis of GR – equivalency principle – do exist. Thus, in all Eotvos-experiments the measurements of forces of gravitation were made in the extremely limited physical conditions, at constant temperature and small accelerations of test bodies (Chen and Cook, 1993, Haugan and Lammerzahl, 2001). The approximation of appropriate GR results in the area of high accelerations of bodies, strictly speaking, is incorrect. The interrelation of the external accelerations, for example, of elastic forces applied to a test body, and force of gravitation acting on this body, follows from the deep unity of electromagnetic and gravitational interactions and, according to the phenomenological description, can be considered as gravitational analogue of Faraday' law of induction and Lentz' rules (Dmitriev, 2001, 2009a). The search for non-classical effects in gravitation in experiments with precision weighing of accelerated moving bodies (oscillating, rotating, being heated up etc.) is logical and expedient. Yet D.I.Mendeleev pointed out: « If it is possible to achieve something in understanding of gravitation and weight, then in no other way and most likely by the most precise weighings and observations of oscillations taking place at that time» (Mendeleev, 1950).

There are distinguished two ways of exact weighing of bodies: static and dynamic. In static weighing the test body is motionless relative to the Earth and weight of the body is determined by the size of elastic or electromagnetic force compensating the gravity; this technique directly corresponds to definition of concept « weight of a body ». In dynamic weighing the beam of weights and a test body make slowly fading oscillations, and average value of the weight measured is determined by elongations'method, by fixing and averaging some extreme values of readings displayed on the scale of weights; in that case the test body experiences some well marked accelerations, which are described by an infinite set of time derivatives from body displacement. Obviously, the physical conditions of dynamic and static weighings essentially differ, though in practical metrology of weight the results of both techniques of weighing are often believed to be identical. Just dynamic weighing is informative in researches into interrelation of gravitational and electromagnetic (elastic) forces.

Of special interest are the measurements of acceleration of free falling of the test bodies underlying the ballistic methods of gravimetry. At free falling a body the interaction of gravitational and foreign forces, by definition, is excluded, but this ideal state is achieved only under condition of absence of own oscillatory or rotary movement of a test body.
Preconditions of search of interaction of electromagnetic and gravitational forces are the results of various Gravity Electro-Magnetism theories which are based on modified GR'equations (Bini et al., 2008, Schmid, 2009). Though the observable effects predicted in such theories are usually extremely small, some worthy positive results were received in some laboratory experiments (Tajmar et al., 2008, Woodward, 2009).
The interrelation of gravitational and electromagnetic forces is especially important in the analysis of properties and reasons of inertia, propulsions' problems, and search for new principles of movement. Correctly executed gravitational laboratory experiment can and should be the basis for formulations of new concepts in gravitation including, supplementing and developing the known GR approaches.

ACCELERATION OF EXTERNAL FORCES, GRAVITY AND INERTIAL MASS OF A BODY

In distinction from "geometrical", the "field" concept of gravitation describes the gravitational interaction of bodies similarly to other kinds of physical interactions - electric and magnetic. Thus the concept of the "material" gravitational field related to sources - the gravitational mass - and characterized by the set of parameters (potential, velocity, impulse, moment) is considered. The advantage of the field, basically phenomenological concept of gravitation consists in an opportunity to use for its development some separate analogies of the gravitational and electromagnetic phenomena, and in their direct experimental check. Thus, gravitational fields, certainly, should have the properties similar, but not identical to properties of electromagnetic fields.
In (Dmitriev, 2001) on the basis of the noted analogies the assumption of original reaction of the gravity force acting on a test body, on its acceleration $\vec{a}$ caused by action of external not gravitational (for example, elastic) forces is put forward. Change $\Delta\vec{g}_{p,c}$ of acceleration of the gravity, similar to the phenomenon of Faraday's induction law in view of Lenz' rule, at simple linear approximation, is equal to

$$\Delta\vec{g}_{p,c} = -\alpha_{p,c}\vec{a} \quad , \qquad (1)$$

where indexes p,c indicate mutual, passing (p) or a contrary (opposite) (c), orientation of a vector $\vec{g}_0$ of normal acceleration of a gravity and vector $\vec{a}$ of acceleration of external force, Figure 1.

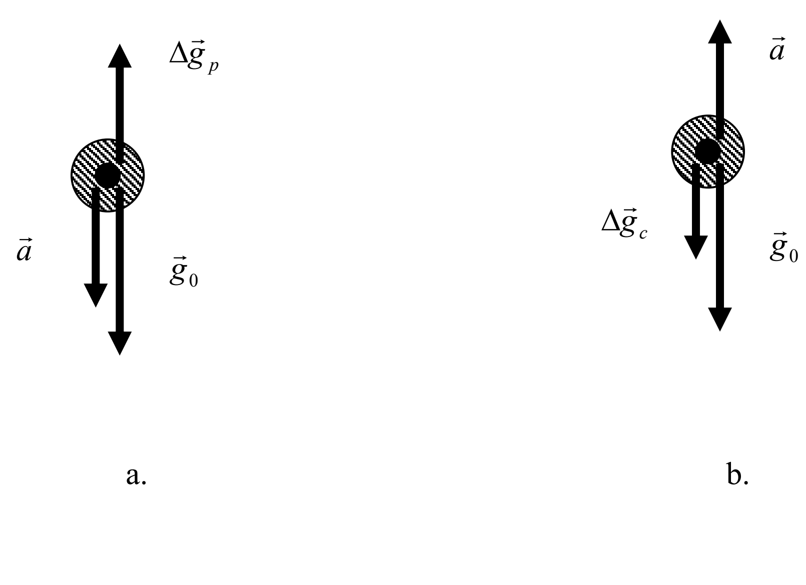


FIGURE 1. a. Changes $\Delta\vec{g}_p$ in gravity force acceleration acting on test body while body is falling down with acceleration $\vec{a}$.
b. Changes $\Delta\vec{g}_c$ in gravity force acceleration while body is moving up with acceleration $\vec{a}$.

Rough estimations of the order of value of dimensionless factors α_p and α_c, which the gravitational interrelation of gravitational and electromagnetic fields specify, were executed in mechanical experiments with weighing of two coupled mechanical rotors with the zero full moment, with a horizontal axis of rotation, and in the analysis of the shock phenomena (Dmitriev, 2002). For metal not magnetic test bodies it is $\alpha_c \approx 10^{-2}$, $(\alpha_p - \alpha_c) \approx 10^{-7}$. By consideration of thermal chaotic movement of microparticles of solid bodies the consequence 1, in view of an inequality $\alpha_p \succ \alpha_c$, is the negative temperature dependence of gravity, also observed in the experiment (Dmitriev, Nikushchenko and Snegov, 2003, Dmitriev. 2008). Measurements of anisotropy of weight of a crystal with a big spatial difference of speeds of longitudinal acoustic waves also specify to nonzero value of a difference $(\alpha_p - \alpha_c)$ (Dmitriev and Chesnokov, 2004).

Definition of factors α_p and α_c of electromagnetic (elastic) and gravitational forces interaction has allowed to give a simple physical interpretation to inertial mass of a body. In (Dmitriev, 2008b, 2009b) in the description of balance of the elastic (electromagnetic) and gravitational forces acting on the test mass on the part of remote mass (for example, stars), according to idea of E. Mach about the gravitational nature of inertial forces, the ratio between inertial (m_i) and gravitational (m_g) masses is obtained,

$$m_i = m_g(\alpha_p + \alpha_c) \ . \quad (2)$$

Equation 2 shows the direct proportionality of inertial and gravity masses of a body, and the relation of theses masses, contrary to the known postulate of "geometrical" model of gravitation, generally speaking, is not a constant.

Equation 1 shows the relation of change of gravity acceleration with acceleration $\vec{a}$ of external forces, but in so doing it is necessary to take into account that the absolute size $\Delta g_{p,c}$ of an increment of acceleration should also depend on magnitude g_0 of normal gravity acceleration. Generally, in view of influence of forces of the gravitation caused by remote surrounding masses (stars), in movement of a test body on a vertical there should be carried out the equation

$$\alpha_{p,c} = A_{p,c}(g_0 + g') \ , \quad (3)$$

where g' - a projection of acceleration of forces of gravitation on the part of the remote masses located in a solid angle 2π, on the direction of the accelerated movement of body. Here the dimensional factors $A_{p,c}$ are universal and characterize the action on a test body of not only the gravitational field of the Earth, but also the fields of the gravitation created in all surrounding masses.

The resultant forces of gravitation acting on the motionless or moving with the constant speed test body from direction of remote masses, uniformly distributed in space in a full solid angle 4π, it is approximately equal to zero, while the magnitude g' determines the inertial properties of a body, Figure 2.

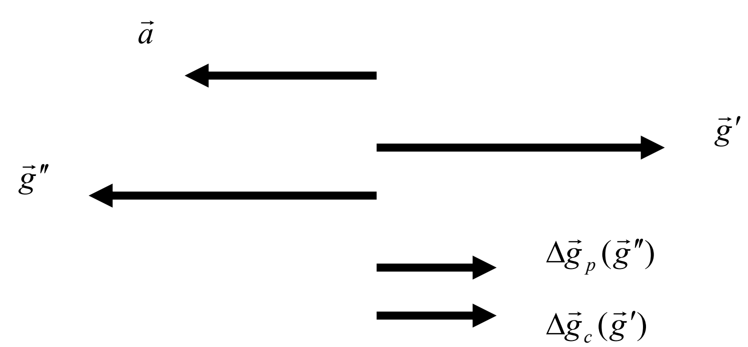


FIGURE 2. Mutual orientation of a vector of acceleration of not gravitational forces $\vec{a}$ and increments vectors $\Delta\vec{g}_p, \Delta\vec{g}_c$ of accelerations of the gravitation forces acting on test mass from the direction of remote masses (stars). The resulting accelerations ' vectors $\vec{g}'$ and $\vec{g}''$, caused by action of the remote masses located in the left and the right half-spaces in the solid angles 2π, are equal in magnitude and are oppositely directed.

Expressions 2,3 are in agreement with the principle of Mach according to which the inertial properties of bodies are determined by action on them of forces of the gravitation created by all surrounding masses, including rather remote ones.

INERTIAL MASS ANISOTROPY

As is known, GR excludes the practical observability of anisotropy of inertia (Hughes, 1960). Consequence of 2,3 is an appreciable difference of inertial mass of a test body at its accelerated movement relative to the Earth in horizontal and vertical directions (Dmitriev, 2009b). Let's show it on an example of harmonious oscillator.

For the harmonious, caused by the action of external elastic force, oscillatory movement along a vertical, the average, for the period of oscillation, inertial mass $\hat{m}_i$ of a test body is equal to

$$\hat{m}_i = m_g (A_p + A_c)(\frac{g_0}{2} + g') \ . \qquad (4)$$

In oscillatory movement of this test body along the horizontal, its average inertial mass $\overline{m}_i$ is equal to

$$\overline{m}_i = m_g (A_p + A_c) g' \ . \qquad (5)$$

In 4.5, the resulting magnitude g' of projections of accelerations of gravity forces created by the remote masses in a solid angle 2π, is believed approximately constant and independent from the direction in space. The relative difference of "vertical" and "horizontal" inertial masses, taking $g' \succ\succ g_0$, is equal to

$$2\frac{\hat{m}_i - \overline{m}_i}{\hat{m}_i + \overline{m}_i} \approx \frac{g_0}{2g'} \ . \qquad (6)$$

Experimental estimations of magnitude of inertial mass' anisotropy of a body can be made, comparing the periods of oscillations of linear mechanical oscillator with vertical and horizontal orientations of its axis. For the same purpose it is convenient to use the rotation oscillator, for example a pendulum of high-quality mechanical balance watch, by changing orientation of the balance axis.
The period T of free oscillations of system a balance - spiral of mechanical watch is equal to

$$T = 2\pi\sqrt{\frac{I}{C}} \ , \qquad (7)$$

where I - the moment of inertia of balance ($I \propto m_i$) and C - factor of elasticity of the spiral.

According to 6,7, the period $\hat{T}$ of oscillations of balance in a vertical plane should be more than the period $\overline{T}$ of oscillations of balance moving in a horizontal plane, that is the ideal mechanical watch in position « on an edge » goes more slowly, than in position "flatwise".
The position-sensitivity of mechanical watch is influenced many factors, including, the moment of inertia and quality of a spiral, conformity of an axis of rotation and the centre of inertia of a pendulum, friction in axes of a suspension bracket of a pendulum etc (Paramonov, 1977). With high quality of watch and its careful adjustment, the influence of the specified factors can be reduced practically to zero, and in that case the comparison of daily motion of balance watch in vertical and horizontal positions can be used for an estimation of magnitude of anisotropy of inertial masse 6.
In view of 4-7, the relative difference γ of the daily motion of an ideal watch is equal to

$$\gamma = 2\frac{\hat{T} - \overline{T}}{\hat{T} + \overline{T}} \approx \frac{1}{4}\frac{g_0}{g'} \ . \qquad (8)$$

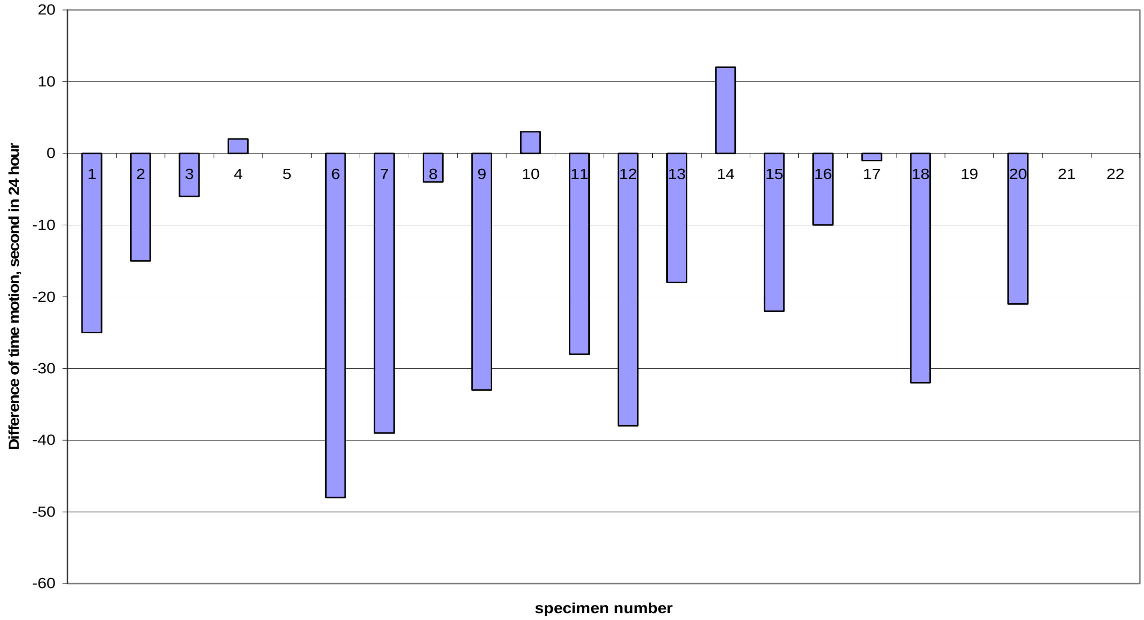


FIGURE 3. A difference of a daily motion of mechanical balance watch «Raketa 2609 » in positions "flatwise" and « on an edge ».

In Figure 3 the results of measurements of position sensitivity of twenty one samples of mechanical watch «Raketa 2609 » manufactured by "Petrodvortsovy watch factory" are given. The difference of an average daily motion of watch in positions "flatwise" and « on an edge » was measured, each of them was measured as an average for two different positions of the head and plane of a dial of watch. The average magnitude of watch motion delay in position «on an edge» has come to about 15 seconds over one day which corresponds to $\gamma \approx 1.7 \cdot 10^{-4}$.

The question of what part of the given value γ is caused by action of physical factors (anisotropy of inertial mass in a gravitational field of the Earth), and what – by technical imperfection of the mechanism of watch still remains open. The difficulty is that even with an appreciable influence on a motion of watch of anisotropy of inertial mass of the pendulum of watch, the position-dependence of a daily motion of watch can be reduced almost to zero by technical means of adjustment. Thus the "physical" delay of a watch motion can be artificially compensated by adjustment of watch which complicates an objective estimation of magnitude of such effect.

Therefore the careful analysis of all technical factors influencing the position sensitivity of balance watches and clockworks used in such experiments is necessary for obtaining of objective data. Nevertheless, the given average result is in agreement with physical preconditions noted above and can be the basis for setting up precision experiments with use of mechanical oscillators on measurements of prospective anisotropy of inertial mass.

Note, if the result shown in Figure 3 gives a true estimation of magnitude order of a relative difference of inertial mass in horizontal and vertical directions, then, according to 8, gravitational field-intensity g' created by all indefinitely remote masses located in a solid angle 2π relative to a point of observation, the said intensity is approximately one thousand times the magnitude of normal acceleration of gravity on the surface of the Earth. In view of gravitational analogue of the Faraday's induction law 1, such rather strong "interstellar" gravitational field, apparently, is also the main physical reason of inertial properties of bodies.

The precision measurements of anisotropy of inertial mass of bodies in a non-uniform gravitational field will confirm validity or an fallacy of the above estimation and as a consequence the validity of the phenomenological "field" concept of gravitation in the description of inertial properties of bodies.

FREE FALLING OF A MECHANICAL ROTOR WITH A HORIZONTAL AXIS

It is known, that weight of motionless bodies is directly determined by acceleration g_0 of free falling. For oscillating and rotating test bodies the measurement of such acceleration is not trivial. To laboratory weighings of rotors of mechanical gyroscopes the set of works (Nitschke and Wilmarth, 1990, Quinn and Picard, 1990, Faller et al., 1990) is

devoted. Such measurements were usually carried out with the purpose of experimental check of a equivalence principle, or various gravitoelectric (gravitomagnetic) models. In most cases, in these experiments the axis of a rotor was oriented vertically and, as a whole, the positive effect was absent (Luo et al., 2002). In paper (Dmitriev and Snegov, 2001) the results of exact weighing of two coaxial rotors with a horizontal axis and with the zero total moment J_{Σ} are given, and its weights which have shown little change, dependent on angular speed of rotation of a rotor. The explanation of these results the possible precession a gyroscope is complicated, connected to rotation the Earth, which essentially could to influence indications of weights, owing to inexact performance of equality $J_{\Sigma} = 0$. In much smaller degree the precession effects influence on results of measurement of size of acceleration by freely falling of rotor. Thus physical conditions of interaction of a falling rotating rotor with the centre of gravitation (Earth) essentially differ from conditions of weighing of a rotor on based laboratory weights.
In described simple experiment (Dmitriev, Nikushchenko and Bulgakova, 2009) the acceleration of free falling of container with the two, located coaxially, rotors of mechanical gyroscopes placed inside it was measured Figure 4; the device and characteristics of the container are given in (Dmitriev and Snegov, 2001).

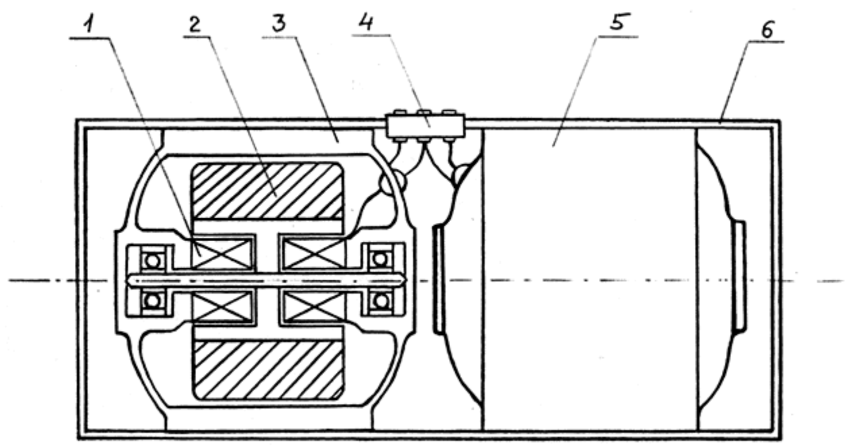
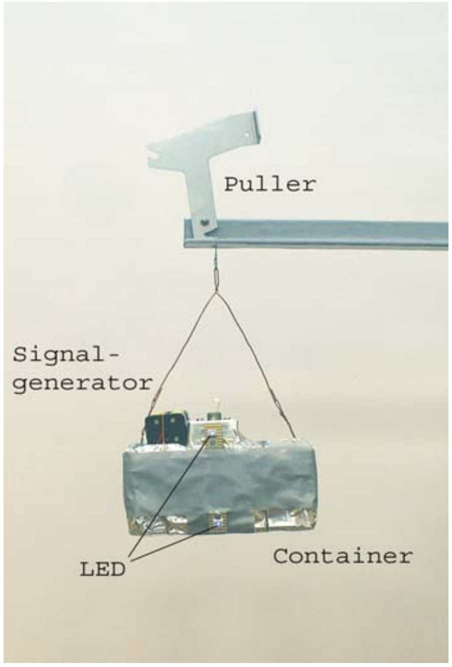


FIGURE 4. The device of the container. 1 - electric coils of the engine of a gyroscope, 2 - a massive cylindrical part of a rotor, 3 - the case of the first gyroscope, 4 - plugs of power supplies of engines of gyroscopes, 5 - the case of the second gyroscope (it is shown without a section), 6 - the case of the container.

On the container the compact highly stable generator of pulses connected to two differ-coloured light-emitting diodes, located along a trajectory of falling of the container is fixed. Appearance of the container with the device for throwing down is shown in Figure 5.



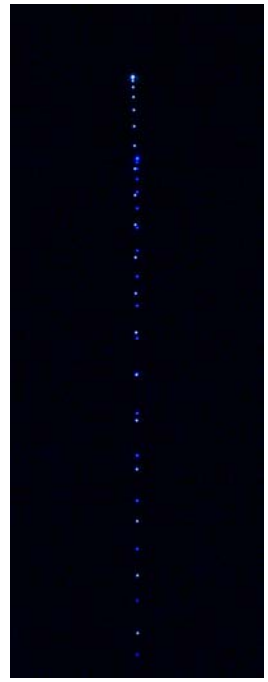


FIGURE 5. Container with the device for throwing. **FIGURE 6.** An example of the container falling trajectory photo

Distance on centre to centre of aperture stop (holes), established before light-emitting diodes is $l = 76.25mm$, frequency of impulses $F = 56.25Hz$, duration of impulse optical signals $0.13ms$. The trajectory of the falling container was photographed by the digital camera with exposure $0.6 - 0.8s$. An example of such photos is shown in Figure 6. Coordinates of marks (the centres of holes) were digitized by computer.

The calculation of acceleration g of free falling container was carried out under the formula

$$g = \frac{(\Delta_2 - \Delta_1)F^2}{N^2}, \qquad (9)$$

where Δ_1, Δ_2 - absolute lengths of the next sites of the trajectories, containing N marks; the scale of the image was defined by distance l between light-emitting diodes. For reduction of influence of aberration of the image owing to distorsion, the average scale of the image paid off on three readout of length l - in the top, central and bottom parts of a trajectory. The size $\overline{g}$ in separate measurement was determined as average value of acceleration, designed on two trajectories appropriate to two groups of color marks on the image.

The example of the measured values of acceleration of free falling container in conditions (1) $\omega = 0$, (2) $\omega \neq 0$ and (3) $\omega = 0$ (upon termination of time rotation of rotor) is shown in Figure 7.

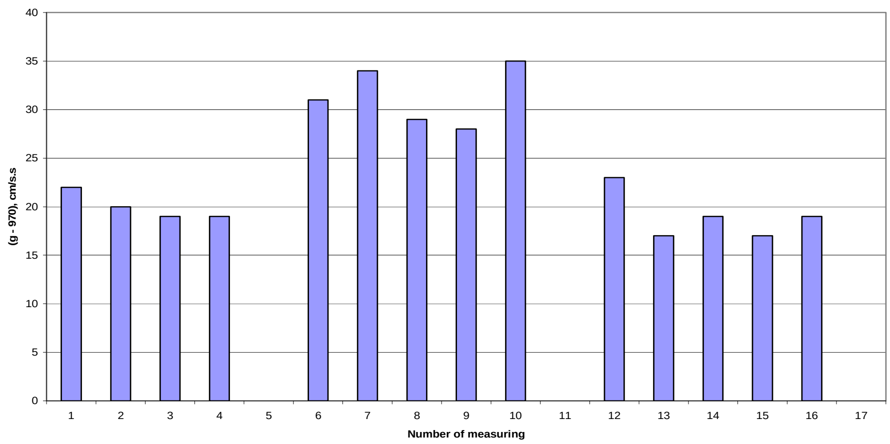


FIGURE 7. The example of the measured values of acceleration of free falling container. 1. $\omega = 0$ (N. 1-4), 2 $\omega \neq 0$ (N. 6-10), 3. $\omega = 0$ (N. 12-16).

The maximal angular velocity of rotation of a rotor $\omega \approx 20000 rpm$, rotation time of rotor is 14-15 mines, duration of one cycle of measurements from 4-5 pictures about 2 minutes.

It was processed over 200 pictures, thus the increase of acceleration of free falling of a rotor was regularly observed at transition from a condition (1) to a condition (2) with average size $\Delta\overline{g} = 10 \pm 2cm/s^2$. At smooth reduction of speed ω of rotation of a rotor the size $\Delta\overline{g}$ also decreased, falling up to zero at $\omega = 0$. In the specified in figure measurements both rotors rotated in one direction and the maximal full moment of rotation of rotors was equaled $J_\Sigma \approx 0.2kg \cdot m^2/s$.

The reason of an appreciable divergence of the measured absolute value of acceleration $\overline{g}$ of a gravity at $\omega = 0$ (about 990 cm / s^2) and standard, at latitude of Saint Petersburg (about 982 cm / s^2), apparently, are discrepancies in display of scale l, errors of absolute value of frequency F of the generator and also the small local (technical) changes of $\overline{g}$. Geographical orientation of a vector of the moment of rotation of a rotor, N-S or W-O, did not influence on results of measurements $\Delta\overline{g}$. Daily dependence of size $\Delta\overline{g}$ also it was not observed.

At horizontal orientation of an axis of rotation of a rotor the each of its particles simultaneously participates in two linear oscillation in horizontal and vertical planes.

Thus of acceleration of particles at their vertical oscillations by an infinite set of derivatives on time from linear displacement are described. As it was marked in (Dmitriev, 2001, 2008a, 2009a) in these conditions it is possible to expect display of "nonclassical" properties of gravitation which mentioned some more D.Mendeleev .

Free falling of masse oscillated along a vertical physically essentially differs from circular (orbital) movement of such masse. Therefore the result received by us does not contradict the results of exact measurements of precession a gyroscope in a circumterraneous orbit.

Relative change $\Delta g/g$ of acceleration of free falling of the container in the described experiment is equal to $\approx 10^{-2}$. Taking into account that the mass of a rotor (500 gram) amounts to $1/3$ mass of the whole container, the relative change $\Delta g/g$ reduced to the rotor mass is equal to $\approx 3 \cdot 10^{-2}$. It is possible to assume that if in a capacity of such "rotors" to use the nuclei of atoms with spatially oriented spins (the set of such atoms forms a macro-dimensions test body) then at high concentration of oriented nuclei in a test body the spatial dependence of acceleration of free falling of a body on orientation of rotors will be much higher than the specified one.

Further experimental researches into free falling of rotating (oscillating) in a vertical plane of either masses or samples of materials with oriented nuclear spins, with use of precision measuring instruments, for example, interferometric ones, seem rather expedient.

CONCLUSIONS

The experimental results described above are obtained by simple technical means and are certainly of a preliminary character. At the same time, it is known that viable ideas in physics quite often prove themselves in technically simple experiments. Logical transition from statics to dynamics, realized in experimental gravitation, opens the prospect of establishment of new properties of gravitation which in the future can get the big scientific and practical values. It creates the prospects of effective solutions and propulsion-problems. The leading role in achievement of such targets belongs to experiment. The practical step to new physics of gravitation should be precision experimental researches into dynamic effects in gravitation. Among them it is necessary to note:

- measurement of temperature dependence of gravitation force;
- static and dynamic measurements of weights of test bodies rotating or oscillating in a vertical plane;
- measurement of anisotropy of crystals weights and measurements of anisotropy of inertial mass of bodies;
- measurement of acceleration of a free falling rotor at various orientations of axis of rotation, and also the samples with artificial orientation of nuclear moments (spins);
- measurements of spatial dependence of restitution coefficient at elastic impacts of solid bodies.

Experiments with weighing of accelerated moving bodies will give useful information on complex, going beyond the scope of well-known theories properties of gravitation. Careful analysis of these results will allow to expand and complement the concepts based on the general theory of relativity, and probably to open the ways to new physics of gravitation and new principles of movement.

NOMENCLATURE

A_c = coefficient of interaction of elastic and gravity forces by counter of $\vec{a}$ and total vector of gravity force ($m^{-1} \cdot s^2$)

A_p = coefficient of interaction of elastic and gravity forces by passing of $\vec{a}$ and total vector of gravity force ($m^{-1} \cdot s^2$)

$\vec{a}$ = acceleration vector of external force (value of vector, $m \cdot s^{-2}$)

α_c = degree of interaction of elastic and gravity forces by counter of $\vec{a}$ and $\vec{g}_0$ (#)

α_p = degree of interaction of elastic and gravity forces by passing of $\vec{a}$ and $\vec{g}_0$ (#)

C = factor of elasticity of the spiral ($kg \cdot m^2 \cdot s^{-2}$)

Δ_1, Δ_2 = lengths of the next sites of the trajectories (m)

$\Delta\bar{g}$ = average difference of measured values of acceleration of free falling container ($m \cdot s^{-2}$)

$\Delta\vec{g}_c$, $\Delta\vec{g}_p$ = increments of acceleration of gravity (value of vectors, $m \cdot s^{-2}$)

F = frequency (s^{-1})

g = acceleration of free falling container ($m \cdot s^{-2}$)

$\bar{g}$ = average acceleration of free falling container ($m \cdot s^{-2}$)

g_0 = normal acceleration of gravity ($m \cdot s^{-2}$)

g' = resulting magnitude of projections of accelerations of gravity forces created by the remote masses in a solid angle 2π ($m \cdot s^{-2}$)

$\vec{g}'$, $\vec{g}''$ = The resulting accelerations ' vectors, caused by action of the remote masses located in the left and the right half-spaces (value of vectors $m \cdot s^{-2}$)

γ = the relative difference of the daily motion of an ideal watch (#)

I = moment of inertia ($kg \cdot m^2$)

J_Σ = full angular momentum ($kg \cdot m^2 \cdot s^{-1}$)

l = distance (m)

m_g = gravitational mass (kg)
m_i = inertial mass (kg)
$\widehat{m}_i$ = average vertical inertial mass (kg)
$\overline{m}_i$ = average horizontal inertial mass (kg)
N = number of marks (#)
T = period of free oscillations (s)
$\widehat{T}$ = period of oscillations of balance in a vertical plane (s)
$\overline{T}$ = period of oscillations of balance moving in a horizontal plane (s)
ω = angular velocity ($rad \cdot s^{-1}$)

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