

Description of Vibrational Balance as an Instrument for Studying the Properties of Time, and Analysis of Its Operation

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This article describes the design and explains the operating principle of vibration balance — a laboratory device designed to register effects caused by local deviations from the fundamental constant of the velocity with which causes transit to effect (the fundamental velocity of the flow of time). These effects, predicted in the framework of Kozyrev's causal mechanics (1958), had been confirmed over decades by numerous experiments using various mechanical devices, including vibrational balances of various designs, both in his laboratory at the Pulkovo Astronomical Observatory and during field research expeditions.

Vibration balance represent a conventional equal-arm beam balance in which the support of the central knife-edge of the beam is connected to a vibration mechanism. This mechanism can generate vertical vibrations of the support. The acceleration of the vibration is significantly less than the acceleration of gravity. Therefore, the knife-edge does not separate from the support, resulting only in variable pressure. Consequently, the distance from the center of gravity to the tip of the knife-edge remains constant, and the balance itself do not change their sensitivity. Vertical guides located on the balance column eliminate the possibility of horizontal swaying of the beam support. One of the loads is suspended from the beam on a rigid suspension, while the other load is on an elastic, easily stretchable suspension. Here, the force required to lift the beam will be only a few percent of the force necessary to lift the load on the rigid suspension. Therefore, during vibration, a stable kinematics of the beam is established, in which the beam point O with the rigid suspension does not participate in the vibration, while the point A at the elastic suspension has maximum vibrations, with an amplitude twice to the amplitude a of the central knife-edge C . Since the additional load during vibration is only a few percent greater than the static one, the beam remains rigid, without natural oscillations, i.e., without bending, in accordance with the requirements of static weighing.

In the vibration regime, such a balance of various designs and different sensitivities were tested with a variety of suspensions — a rubber, spring, etc. Let us provide specific data for the balance currently used in our work. These are a second-class technical balance with a capacity of 1 kg. A 1 mm deflection of the pointer tip, which is rigidly attached to the beam, corresponds to a load of about 10 mg. This sensitivity corresponds to a position of the beam's center of gravity

approximately 1 cm below the support point of the central knife-edge. The arm length is $OC = CA = 16$ cm. Secure fastening of the knife-edges in the beam ensures the constancy of this length. Vibrations are carried out at a frequency from 10 to 20 Hz with an amplitude $a \approx 0.2$ mm. Thus, the maximum velocity of the central knife-edge is $v = \frac{2\pi}{T} a \approx 2$ cm/sec, and its maximum acceleration is $w = \left(\frac{2\pi}{T}\right)^2 a \approx 2 \times 10^2$ cm/sec², which is about 20% of the acceleration of gravity. Usually, loads weighing about 700 g are used. One of the loads is suspended from a rubber, the elongation of which by 1 cm is obtained when the load changes by 100 g. Thus, during vibrations, the additional force on the beam is less than 10 g, which, of course, cannot disrupt the rigidity of the beam. The vibrations are absorbed by the rubber, and the load actually does not vibrate.

On this balance, as well as on all other tested systems, a rotation of the beam is invariably obtained, corresponding to an increase in the weight of the load with the elastic suspension. This additional force ΔQ is proportional to the weight of the load Q , where $\Delta Q/Q = 3 \times 10^{-5}$. Therefore, when $Q = 700$ g, then $\Delta Q = 21$ mg, and the corresponding torque rotating the beam of the used balance is equal to 300 dynes $\times$ cm.

Let us now prove that the possibility of the indicated forces is completely excluded by classical mechanics.

1. Abstracting from the balance, let us first consider the force with which a load of weight Q acts on a suspension point that undergoes bounded oscillations of any type. In this problem, kinematics determines dynamics. Therefore, applying the theorem stating that the time-average value of the derivative of any periodic function is equal to zero, we find that the average acceleration of the suspension point and of all points of the system is equal to zero. This means that the force acting on the suspension point remains the same as in statics; it is affected by the weight of the load Q and nothing more. Consequently, on the balance as well, any elastic deformations of the rubber cannot generate an additional force during vibrations capable of rotating the balance beam.

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2. It remains to consider the possibility of the appearance of a torque of forces acting on the beam relative to the support of the central knife-edge. The necessary torque can only be generated by forces acting along the beam. Even if we assume an asymmetry in the horizontal impact of the support on the balance stand, then even in that case, the forces in the beam will be oriented by this asymmetry and must be canceled out by swapping the suspension positions of the loads.

Only the centrifugal acceleration v^2/ϱ can generate the necessary torque, the direction of which depends on the arrangement of the suspensions. At first glance, it might appear that during vibration, the beam undergoes rotations about a fixed point O . In reality, however, the motion of the beam points is more complex. The fact is that the central knife-edge does not separate from the support; it is connected to it and therefore moves strictly along a straight line. Therefore, in the central part of the beam, where the main part of its mass is concentrated, there will be no centrifugal acceleration. As for the point O , it is fixed by the load on the rigid suspension only in the vertical direction, but can freely move horizontally. These horizontal displacements of the point O are very small. Indeed, they are equal to $a^2/2l$ and, consequently, have a magnitude of the order of 0.1 microns. Nevertheless, due to the possibility of such displacements, a peculiar kinematics of the beam arises. During vibration, each point of the beam describes an arc of an ellipse, the minor axis of which is directed along the beam in its mean position. In the sections of the beam from O to C and from C to A , the concavities of these arcs have opposite orientations and generate centrifugal forces having opposite directions. However, due to the large value of v^2 in the section $C-A$, the compensation will be far from complete, and the centrifugal force directed towards A , i.e., towards the suspension point of the load on the elastic fastening, will act on the beam. At the point A , the centrifugal

acceleration will be the greatest. For this point, we obtain $v^2 = \left(\frac{2\pi}{T}\right)^2 a^2 \approx 6 \text{ cm}^2/\text{sec}^2$. It is easy to calculate for this point that the curvature radius of the ellipse is $\varrho = 4l = 60 \text{ cm}$. From this, the centrifugal acceleration turns out to be equal to $0.1 \text{ cm}/\text{sec}^2$. The mass of half of the beam arm is of the order of 20 g. Consequently, we obtain an estimate of the maximum possible centrifugal force acting on the beam of the order of 2 dynes. The entire width of the part of the beam that interests us is of the order of 1–2 cm. Therefore, the torque of centrifugal forces capable of rotating the beam turns out to be no greater than 1–2 dynes $\times$ cm. Consequently, the magnitude of this torque constitutes only a fraction of a percent of the magnitude that is actually observed on the balance, and its direction must depend on the shape of the balance beam.

3. The effect of the weight increase of the load on the elastic suspension is also not explained by the peculiarities of dry friction between the central knife-edge and the support in the vibration regime. One can be convinced of this by lubricating the tip of the knife-edge and the support with liquid machine oil. In this case, the weighing accuracy does not deteriorate, and the weight increase effect of the load during vibrations remains the same.

The presented analysis shows that forces appear on the balance working in the vibration regime, which cannot be explained in the framework of classical mechanics. These forces are directed along the axis of the Earth's rotation and are caused by the pressure of time on causal relationships. Therefore, the effects of their deviation observed on the balance depend on the geographical latitude, which was demonstrated by the conducted expedition work, the report of which was submitted to the Pulkovo Astronomical Observatory.