М2.

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Methodical instructions to perform laboratory work M2

" STUDYING OF DYNAMICS LAWS AND MEASURING OF GRAVITATIONAL ACCELERATION ON THE ATWOOD'S MACHINE "

Brest 2014

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Methodical instructions drawn up in accordance with a model program of physics course for engineering majors. The guidance given necessary for the understanding of the physical processes theoretical information explaining the principle of operation of devices and equipment used, describes a technique experiments, are tasks for independent work. Given control questions and a list of recommended reading.

Methodical instructions to carry out the laboratory work designed for foreign students BrGTU all technology sectors and forms of education.

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EE BrSU named after A.S. Pushkin

LABORATORY WORK M2

"STUDYING OF DYNAMICS LAWS AND MEASURING OF GRAVITATIONAL ACCELERATION ON THE ATWOOD'S MACHINE"

1. GOAL

To use an Atwood's machine to measure the value of gravitational acceleration.

2. INSTRUMENTS AND ACCESSORIES

The unit with the Atwood's machine, set of additional ring-shaped weights.

3. INSTALLATION DESCRIPTION

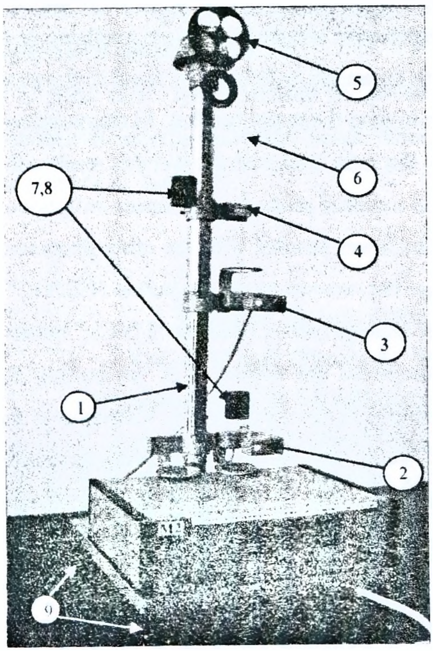

Figure 1.

General view of the Atwood's machine is shown in Figure 1. The vertical column (1) has three brackets: the lower bracket (2) is fixed and the brackets (3) and (4) can be moved along the column and locked in any position by the locking screws. The distance between the brackets can be found with the millimeter scale on the column (1). In the upper part of the column there is a pulley (5) with the string (6) over it with the weights of equal mass tied on its ends (7,8) and the screws for leveling the unit (9). The experimental setup has three additional ring-shaped weights of different masses, which can be placed separately, two and all three together.

4. PREPARATION OF THE UNIT FOR WORK

The device operates in the following way. Set the desired distance between the lower and middle brackets (S_2) and the upper and middle brackets (S_1). Press the "СЕТЬ" . Thus the special magnet prevents free rotation of the pulley.

One of several ring-shaped weights which are available in the set are put on the right load. The load with an weight with is set by hand to the position, where its lower edge coincides with the line on the upper bracket. In this position of the load press the button " ПУСК". When the right load with the weights reaches the middle bracket, the weights are removed and a special photoelectric sensor switches on a stopwatch. When the right load reaches the lower bracket with the other photosensor, the stopwatch is switched off. To continue the measurements the button "СБРОС" is pressed, preparing the stopwatch for further measurements. Press the "ПУСК" button.

Subsequent measurements are started with the putting the right load with a weight to the initial position, as described above. Vibration of the loads are eliminated. Press the button " ПУСК" and so on. Perhaps during motion of the right load it touches the ring to the middle bracket, which are designed to remove the weights, and the further movement of the load is accompanied by vibrations. It is also possible that the right load does not fall right into the receiving window of the lower bracket. For performing measurements of **these effects must be eliminated!** This is achieved by leveling the unit with the screws (9) and a small rotation in the horizontal plane of the middle bracket (3).

Further we use the following notation:

M_{FR} – friction torque; $[M_{fr}]$ = N·m;

m – mass of the weights hanging on the string on the pulley; [m] = kg;

Δm – mass of the weight which is put on the right load; [Δm] = kg;

S_1 – the distance between the upper and middle brackets , i.e. the distance that the load passes with the weight Δm; $[S_1]$ = m;

S_2 – the distance between the middle and lower brackets, i.e. the distance that the load passes without the weight Δm; $[S_2]$ = m;

t – time of movement of the right load at stage 2; [t] = s;

$\boldsymbol{a_1}$ – the acceleration of the right load at stage 1; $[a_1]$ = m/s^2 ;

$\boldsymbol{a_2}$ – the acceleration of the right load at stage 2; $[a_2]$ = m/s^2;

R – the radius of the pulley; [R] = m.

Stage movement with the weight Δm is called stage 1 and the stage of movement without the weight Δm is called stage 2.

The unit allows to make direct measurements of movement time t of the right load on the way **S_2** between the middle and lower brackets for different given values of the weights **Δm**, movement S_1 and S_2.

5. THEORY

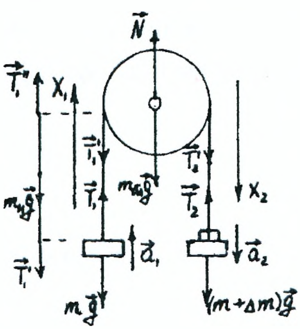

Figure 2.

Consider the pulley which can rotate around the horizontal axis (**Figure 2**). We assume that its mass is negligible, so the moment of inertia **J** of the pulley can also be neglected. A weightless non-extensible string is put on the pulley at the ends of which there are the loads of **m** mass. If we put a weight of a sufficient large mass **Δm** on the right load, the system begins to move (of course in case of absence of friction of the weights of a small mass will bring the system into motion, but if there is friction it will not move). We shall calculate the acceleration of the weights considering that the string does not slip on the pulley. We assume that the dissipative forces which depend upon speed (for example, the forces of air resistance are absent). Two forces exert on the left vertical part of the string: the force $\vec{T}_1'$ from the side of the left load which as per the Newton third law is equal to the force $\vec{T}_1$ in magnitude and opposite in direction, and the force $\vec{T}_1''$ of tension of the string located on the pulley. The figure on the left shows the separate left part of the string and the forces acting on it; we remind that the string is weightless. We write Newton's second law for the left segment of the string :

$$m_{st}\vec{a}_{st} = -\vec{T}_1 + \vec{T}_1'' = 0, \ (m_{st} = 0)$$

$$\vec{T}_1 = \vec{T}''$$

By Newton's third law, the force with which the left vertical portion acts of the string on the portion located on the pulley is

$$\vec{T}_1' = -\vec{T}_1'' = -\vec{T}_1$$

In fact, the force $\vec{T}_1'$ is applied to the pulley. Similar considerations are applied to the right vertical section of the string. For modules forces therefore we have

$$T_1' = T_1 \text{ and } T_2' = T_2$$

We write the system of equations describing the motion of both weights. For this we choose the positive direction of the axes X_1 and X_2 so that they coincide with the direction of movement. Modules accelerations of both weights are equal in absolute value, which we denote by a11, since we are talking about the first stage of the movement. Then Newton's second law of motion of bodies on the first stage (S_1) in projections on the selected axes:

$$\begin{cases} T_1 - mg = ma_1 & (1) \\ (m + \Delta m)g - T_2 = (m + \Delta m)a_1 & (2) \end{cases}$$

The pulley gravity is 0, so as $m_{6n} = 0$. We write the basic equation for the power dynamics of rotational motion

$$T_2R - T_1R - M_{FR} = 0$$

$$(T_2 - T_1)R = M_{FR} \qquad (3)$$

Summing up the equations (1) and (2) with the equation (3) we obtain the expression for the acceleration of gravity:

$$g = \frac{M_{FR}}{\Delta mR} + \frac{a_1(2m + \Delta m)}{\Delta m} \tag{4}$$

If the system moves for a period of time with the acceleration a_1 in stage 1, and then we remove the weight, then the further movement of the system in stage 2 will be carried out with the acceleration a_2, which due to the frictional force will be directed upwards. Its modulus can be determined from the laws of translational and rotational motion forming for stage 2 the same system of equations. Then we get

$$a_2 = \frac{M_{FR}}{2mR} \tag{5}$$

Given the sign of the projection a_2 kinematic equation for the distance S_2 is:

$$S_2 = V_{02}t - \frac{a_2t^2}{2} \tag{6}$$

Since the movement with the weight starts without initial speed, the speed of the right load at the end of stage 1 is the initial speed in stage 2 and is connected with the distance S_1 by ratio:

$$a_1 = \frac{V_{02}^2}{2S_1} \tag{7}$$

From (5), (6) and (7) we can easily obtain the expression for all through the experimentally measured values S_1, S_2, and t:

$$a_1 = \frac{(4mRS_2 + M_{FR}t^2)^2}{32S_1(mRt)^2} \tag{8}$$

Putting equation (8) into (4), we obtain

$$g = \frac{M_{FR}}{\Delta mR} + \frac{(2m + \Delta m)(4mRS_2 + M_{FR}t^2)^2}{32\Delta mS_1(mRt)^2} \tag{9}$$

If we neglect the friction torque in this equation, we obtain

$$g = \frac{(2m + \Delta m)S_2^{\ 2}}{2\Delta m S_1 t^2} \tag{10}$$

6. ORDER OF PERFORMANCE

1) Choose any value S_1 in the interval between 6 cm to 20 cm , for example , S_1 **= 15 cm**. Set the minimum value S_2 (S_2 **= 5 cm**).

2) Measure at least five times the time **t** movement on the right load at stage 2 using **Δm** = **6.5 g**. Find the average time of movement <t>.

3) Using the equation and the information contained in the **Theory** obtain the equation for the gravitational acceleration g , taking into account the friction torque (9).

4) From the obtained expression (9) , substituting the measured values in paragraph 2 <t> time and all other known parameters, **find the gravitational acceleration g**. The friction torque of this installation M_{FR} **= 5.3 · 10 ⁻⁴ N·m**, masses ***m*** **= 0.064 kg** , the radius of the pulley ***R*** **= 0.0415 m**.

5) Using (10) to determine the gravitational acceleration g, excluding the friction torque.

6) Draw a conclusion about the results of this work and the possibility to measure the gravitational acceleration g with the Atwood's machine .

7. CONTROL QUESTIONS

1) What does method of the gravitational acceleration measuring on the Atwood's machine consist in?
2) Formulate the laws of dynamics that were used in this study.
3) How to determine the gravitational acceleration g, excluding the friction torque?

8. LITERATURE

1) Чопчиц Н.И., Гладыщук А.А., Янусик И.С. Лабораторный физический практикум "Механика" / Методическое пособие для студентов технических специальностей. – Брест, изд-во БрГТУ, 2011. – 80 с.

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