Laboratory work №1.2

Study of the laws of translational motion on the Atwood device

Tools: 1) Atwood device (with set of basic and additional loads).

Purpose: to study the laws of kinematics and the dynamics of translational motion, to determine experimentally the acceleration of gravity.

Theory

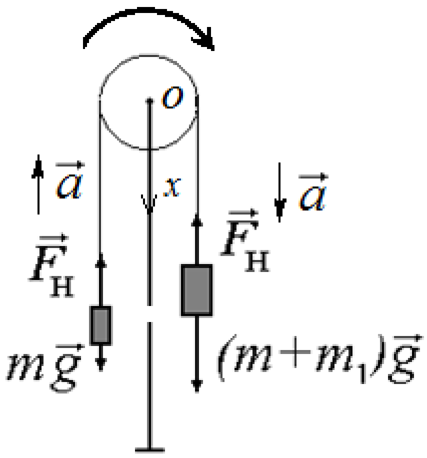

Fig. 1

Throw a weightless nonstretchable line with loads m and $m+m_1$ at the ends over a lightweight block (Fig. 1).

According to Newton's second law, the product of the a material point's mass by its acceleration is equal to the vector sum of the forces acting on it

$$ma = \sum F_i \quad (1)$$

Summing the corresponding forces, write the equation of motion (1) for each load.

The left load of mass m gets acceleration a, directed upwards, under the action of two vertical forces: the tension force of the line F_t (directed upwards) and the gravity force mg (directed downwards):

$$ma = mg + F_t. \quad (2)$$

On the right load of mass $m + m_1$ act gravity force $(m + m_1)g$ and the tension force of the line F_t, because of which the right load gets an acceleration a directed downwards:

$$(m + m_1)a = (m + m_1)g + F_t, \quad (3)$$

Due to the inextensibility of line the acceleration modulus a of the both bodies is the same.

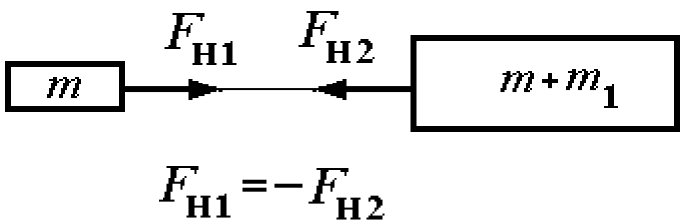

Fig. 2

According to Newton's third law, when two bodies interact, one of them acts on the other with the same force, but with opposite direction, as the second on previous one. These forces are oppositely directed along the straight line connecting these bodies (material points) (Fig.2).

A lightweight block and a weightless line do not change the magnitude of these interaction forces, but only their direction. Both forces $\boldsymbol{F_{t1}} = \boldsymbol{F_{t2}} = \boldsymbol{F_t}$ become directed upwards (Fig. 1).

Choose an arbitrarily positive direction of the Ox axis, for example, downwards, and write down the second Newton's law for both loads in the projections onto this axis:

$$\begin{cases} -ma = mg - F_t \\ (m+m_1)a = (m+m_1)g - F_t, \end{cases} \qquad (4)$$

The simultaneous solution of these equations gives the value of the acceleration of gravity.

$$g = \frac{2m + m_1}{m_1} a \qquad (5)$$

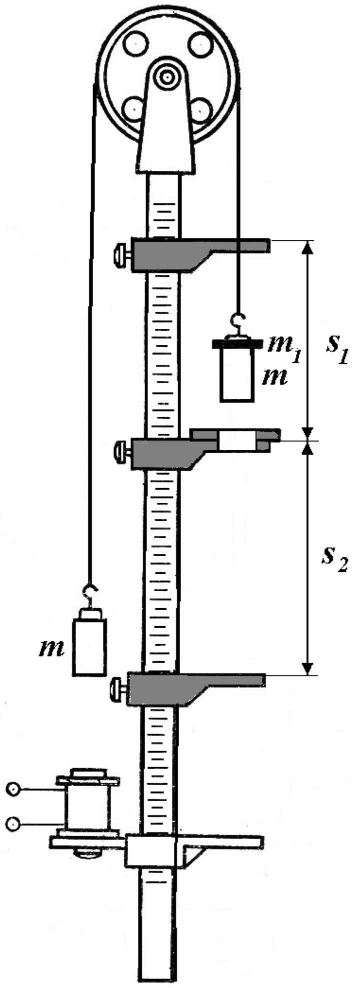

Fig. 3

Device

The Atwood device is shown in Fig. 3. It consists of a vertical frame, where a scale is drawn. At the top of the frame, a lightweight block is fixed, rotating with low friction around the horizontal axis. A thin line with loads of the same mass *m* at its ends is thrown through the block.

The Atwood device makes it possible to receive uniform and uniformly accelerated motion of loads.

If the masses *m* of both loads are the same, then the system is in equilibrium – either the loads are motionless, or the loads move at a constant speed.

If on one of the loads, for example, the right one, we put an additional small load (overload) of mass m_1, both loads begin to move uniformly accelerated. The both loads will have the same acceleration.

Three brackets can move along the frame. The upper bracket serves to set the starting position of the right load.

In the middle bracket there is an opening through which the right load can freely pass, and the overload is removed on the move. Since the masses of loads become equal, their further motion takes place without acceleration, i.e. with a constant speed.

The lower bracket marks the end of the right load path.

We can specify distances:

- s_1, on which the loads move uniformly accelerated;
- s_2, on which the loads move uniformly.

With the help of the electronic stopwatch, which is turned on and off automatically by photoelectric sensors, we can measure the time interval t when the loads pass the distance s_2, moving uniformly.

If the overload is removed during the motion (by means of the middle circular bracket), then further motion of the system will occur with a constant speed v equal to the speed at the moment of removing of the overload. It is equal to the final speed got by the loads during uniformly accelerated motion on the path s_1. According to the kinematics formulas

$$v^2 = 2as_1. \quad (6)$$

On the section s_2, the motion is uniform, so the velocity is equal to the path divided by the time,

$$v = \frac{s_2}{t}. \quad (7)$$

From equations (5) - (7) it is possible to express the acceleration of gravity

$$g = \frac{(2m + m_1)s_2^2}{2m_1 t^2 s_1}. \quad (8)$$

This is working formula.

Measurements

1. Put the right load to the upper position, align its lower base with a stroke on the upper bracket, fix it with an electromagnetic brake, pressing the "RESET" button.
2. Put one of the overloads m_1 on the right load.
3. Set the middle bracket at a certain distance s_1 from the top bracket and s_2 from the lower one. Measure the distances s1 and s2 on the scale and record them.
4. Press the "START" button and, using the electronic stopwatch, determine the time t of the of the larger load motion on the path s_2.
5. Return the system to its original state. For this, press the "RESET" button, move the right load to the upper position and press the "START" button again.
6. Changing the overload, repeat the experiment 3 times with each of them.

7. Calculate the acceleration of gravity g by formula (8). Write down the measurements in the table. Answer write in the form

$$g = (\langle g\rangle \pm \Delta g)\ \text{m/s}^2 \text{ with } \alpha = \ldots$$

Control questions

1. Give the formulas of the path for uniform and uniformly accelerated motion.
2. Formulate Newton's second law.
3. Why does the load move uniformly accelerated at s_1 and uniformly at s_2?
4. What the simplifying assumptions are used in this work for receiving the formula for the acceleration of gravity? Why, under these assumptions, the tension forces of the lines on both sides of the block are equal?
5. Will the tension forces of the lines on both sides of the block be equal, if the mass of the block can not be neglected? Why?
6. How will the acceleration of loads change if the lines is considered to have weight?

№	m_1,	s_1, m	s_2, m	t, s	g_i m/s^2	$\langle g\rangle$ m/s^2	Δg_i m/s^2	$(\Delta g_i)^2$	$S_{\langle g\rangle}$, m/s^2	α	$t_{\alpha,n}$	Δg, m/s^2	E, %
1													
2													
3													
4													
5													
6													
m =													