LABORATORY WORK № 1

OSCILLATIONS OF A SPRING PENDULUM

Purpose of the laboratory work

1. Experimental study of spring pendulum vibrations and introduction to methods for determining the parameters of mechanical vibrations.

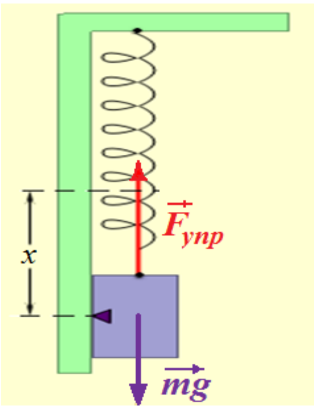
2. Determination of the spring constant.

Experimental equipment, instruments and accessories

The laboratory stand includes a vertical support structure with guide slots 1, as well as a set of springs and a movable carriage 2, in the hole of which an additional load can be fixed.

Devices and accessories include an optical sensor 4, a computer with the necessary software.

Theoretical part



In linear elastic systems, Hooke's law applies:

$$F_{el}=kx \tag{1}$$

F_{el} - is the value of the elastic force, for example, of a spring, measured in Newtons,

k - the spring stiffness coefficient (N/m),

x - the tension/compression of the spring (m) from the position of its undeformed state.

Consider the forces acting on a spring pendulum located vertically (we neglect the forces of resistance to movement). These are: the force of gravity mg and the elastic suspension force F_{el}, which tends to return the spring to its original, unstretched position.

Newton's second law for this case can be written as follows:

$$m\vec{a} = m\vec{g} + F_{el} \tag{2}$$

If x - the displacement of the body from its static equilibrium position, in which the spring lengthening is equal to the static x_{st}, then the projection on the x-axis:

$$m\ddot{x} = mg - k(x_{st} + x), \tag{3}$$

where $\ddot{x}$ - is the acceleration of the body, defined as the second derivative of the displacement x with respect to time, and the value $x_{st} + x$ is the total displacement of the spring.

The condition for the equilibrium of a body of mass t on a spring is the equality of gravity and the static elastic force of the spring:

$$mg = F_{el}.$$

So, the equilibrium static elastic force of the spring is determined by the static displacement from the equilibrium position x_{st}:

$$mg = kx_{st} \tag{4}$$

Using (4), equation (3) takes the form:

$$m\ddot{x} = -\kappa x,$$

which after division by m allows it written as:

$$\ddot{x} + \omega^2 x = 0, \tag{5}$$

$$\omega = \sqrt{\frac{k}{m}}$$

Expression (5) is a differential equation of free vibrations. The solution of the differential equation (5) is a harmonic oscillation of the form:

$$x = A\cos(\omega t + \varphi), \tag{6}$$

Here A, φ - are the amplitude and initial phase of vibrations, and the value ω is called the frequency of natural vibrations. The oscillation period T is determined by the frequency of vibrations:

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}, \tag{7}$$

Basic calculation formulas:

Using two different loads m_1 and m_2, then the spring constant is estimated from the corresponding periods T of natural vibrations (dynamic method):

$$\boxed{k = 4\pi^2(m_2 - m_1)/(T_2^2 - T_1^2)}$$

Description of the laboratory installation

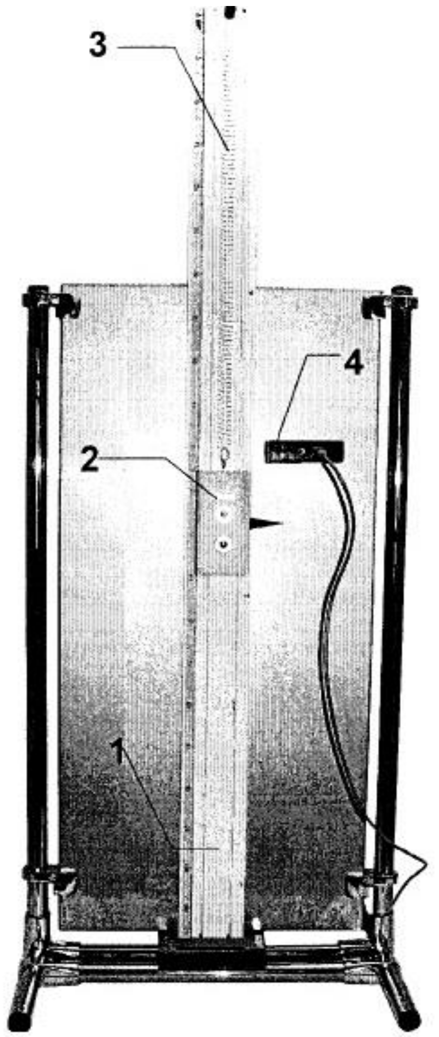
To assess the spring constant using the dynamic method, a spring pendulum is used, which is a carriage (2), suspended on a spring (3). To make the experiment, the load suspended on the spring must be released and allowed to oscillate freely. To measure the oscillation period, an optical sensor (4) is used, which is set so that the flag on the carriage intersects the optical axis of the sensor when the pendulum oscillates.

The set has two springs of different stiffness, and the carriage weight M attached removable additional weights weight m.

The procedure of conducting laboratory work

1. Write down the mass of the carriage M and the mass of the additional load m:

m=50±1 g.	M=104±2 g.



1. Assemble the laboratory unit by fixing the end of one of the springs to the top of the support structure, and attaching the carriage without a load to the other end. Place the optical sensor in the path of the carriage plate.

2. Connect the optical sensor to the computer's USB port.

3. After turning on the computer, run the program "physics Workshop". On the device panel, select the appropriate experiment scenario (Alt+C)

4. Start the measurement for the selected sensor (Ctrl+S)and immediately, immediately after starting, lightly push the spring carriage along the guide.

5. After a few swings of the pendulum, stop the measurement (Ctrl+T).

6. Process the received data in accordance with the scenario, for which:

* select an area with multiple overlap pulses to view it in detail and zoom in (Alt+left mouse button);

* measure the period of oscillation of the pendulum along the leading or trailing edges of adjacent even (or odd) overlap pulses by placing a yellow (left mouse button) and green marker (right mouse button) on the corresponding edges of the overlap pulse.

7. Perform period measurements 5 times using different fronts of different pulses. Record the measurement results in table 2.

8. Attach an additional load to the carriage. Repeat steps 5-8 for the weighted pendulum. Record the measurement results in table 2.

9. Replace the spring with another one from the supplied kit. Then perform the experiment again according to points 5-9. Record the measurement results in table:

To determine the period, it is necessary to calculate the number of oscillations N during time t (1 complete oscillation - 2 rectangular pulses on the computer program screen).

Spring 1.

i, №	period of the pendulum without load T_{i1}, s	Average period of the pendulum without load $\langle T_1 \rangle$, s	m_1, kg	Period of the pendulum with load T_2, s	Average period of the pendulum with load $\langle T_2 \rangle$, s	m_2, kg
1						
2						
3						
4						
5						

Spring 2.

i, №	period of the pendulum without load T_{i1}, s	Average period of the pendulum without load $\langle T_1 \rangle$, s	m_1, kg	Period of the pendulum with load T_2, s	Average period of the pendulum with load $\langle T_2 \rangle$, s	m_2, kg
1						
2						
3						
4						
5						

4. Processing of measurement results.

Using the results obtained, determine the average values of the oscillation periods for each spring both for an empty cart with a mass of M and for a load with a total mass of M+m or M+2m, using the formula:

$$k = 4\pi^2(m_2 - m_1)/(T_2^2 - T_1^2)$$

As a rule, (m_2-m_1) appeared to be either m or 2m (50 or 100).

5. Write down the results of calculations of spring constants k_1, k_2.

6. Write down the conclusions with the results/

Control questions on the topic of the lesson:

1. Define the period and frequency of oscillations of a spring pendulum.
2. Name the main types of oscillations.
3. Derive the differential equation of undamped oscillations. Write down it's decision and draw a graph.
4. Output formulas for the speed and acceleration of the oscillating body.
5. Write down the formulas for the kinetic, potential, and total energy of the oscillating body.
6. Draw a graph of the period of natural fluctuations depending on the weight of the cargo.
7. Print the dimension of the spring constant.
8. Formulate the Hooke's law for the spring.
9. How is the spring constant of the system calculated when springs connected in parallel and in series?

Situational tasks on a topic:

1. Find the acceleration that occurs during harmonic oscillations of the form: x= 3cos(2t-1).

2. The oscillation is performed according to the law X=0, 4sin5πt. Determine the amplitude, oscillation period, and displacement at t = 0.1 s.

3. Find the kinetic energy of the body oscillating according x(t)=20cos(2t+1), m=2kg.

4. Two spring are connected in series, each have spring constant K, what is the equivalent stiffness of spring?

5. Two springs have spring constant 5 and 10 respectively are connected in series. Calculate combined spring constant.

6. Find the period of oscillation of a spring pendulum if its mass is 100 g and the coefficient of elasticity k=0.1 N/m.

7. Find the coefficient of elasticity of the spring pendulum if its mass is 100 g, and the offset from the position without a load is 5 cm.