Laboratory work №4.2

Investigation of standing waves and determination of self-resonant frequency of string's oscillation

Tools: 1) device for observing standing waves; 2) measuring device.

Purpose: production of standing waves on a string, observation of distribution pattern of amplitudes and quantitative check of formula of string's self-resonant frequency.

Theory

If the string, which is stretched between two points, is taken out of the equilibrium position it will oscillate. The wave, spreading along the string, reflects from string's ends. Because of the superposition of incident and reflected waves, the special oscillations establish in the string.

Features of the wave are that not all points of the string oscillate. Some of them remain motionless and are named **nodes** of standing wave. At the ends of the string at the points of fixation nodes always exist, and between them there are one or several number of antinodes - regions oscillating with a maximum amplitude.

Between two neighboring nodes all points of the string oscillate simultaneously (in the same phase, in-phasely) but with different amplitudes.

Such type of in-phase oscillations with acharacteristic spatial distribution of amplitudes – alternation of nodes and antinodes – is called the **standing wave**. The distance between two neighboring nodes is equal to half of the wavelength.

All points between neighboring nodes simultaneously reach the maximum deflection and simultaneously pass through the equilibrium position. In fig. 1 shows "instant photographs" of points' deflection from equilibrium position in two close moments of time t_1 and t_2. Arrows show the direction of string's points motion.

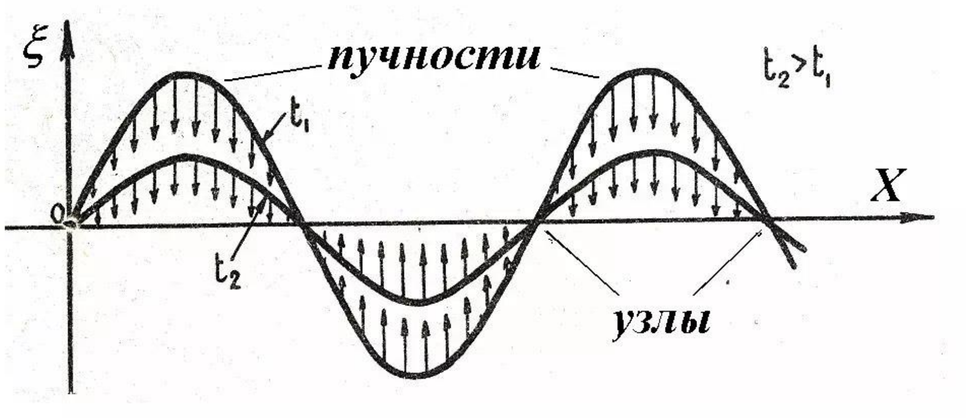

Fig. 1

Fig. 2 shows the string's position through every eighth of period $\frac{T}{8}$. At the beginning all points of the string lie on a straight line.

Then, between the motionless nodes the string begins swelling, which reaches its maximum in a quarter of a period. After this, swelling decreases and the string again becomes straight through the half of period. Further swelling occurs in the opposite direction.

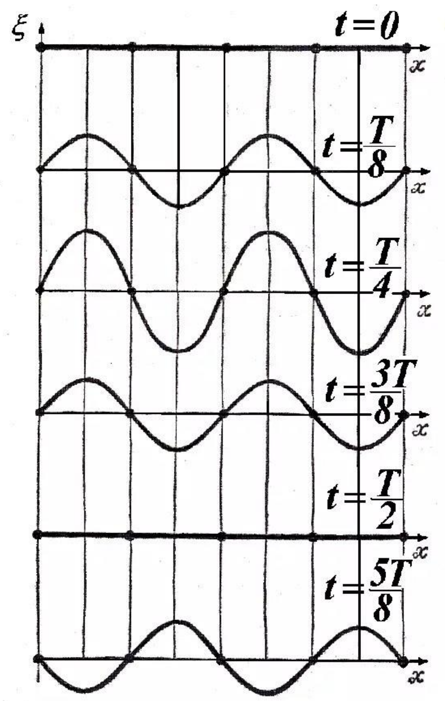

Fig. 2

Every moment a wave is visible and at the same time it stands still; what was the basis to name it the **standing wave**.

Other examples of the standing waves: the standing sound wave inside air tubes (organ, wind instrument), the standing electromagnetic waves in transmission lines or waveguides.

Unlike a traveling wave that can move left or right, the standing wave does not have a propagation direction. This difference can be seen in two figures relating to close moments of time (fig. 3).

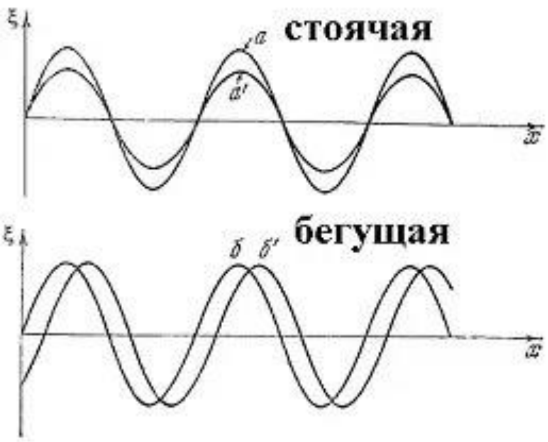

Fig. 3

As the calculation shows (see the Addition to laboratory work 4.1), the oscillations' frequency of a string can be calculated from the formula:

$$\nu_n = \frac{n}{2l}\sqrt{\frac{T}{\rho}},$$

m – mass of the load, that stretch the string, ρ – mass of the unit length of the string material, n – number, indicating the how many standing waves go into the length l of the string.

Thus, in the case of free oscillations of the string standing waves occur in it, which frequencies can take only discrete values, that are named the self-resonant frequencies of oscillations.

Device

The device consists of: a rigid base on which permanent magnets are fastened, the string stretched between the poles of magnets and the string's tension mechanism. One string's end is fixed and the other end is attached to the calibration spring. The second end of the spring is mechanically connected to the device that can change the tension of string.

The tension of the string is measured by an index that moves along the scale when the string tension changes.

The measuring device includes a sinusoidal oscillator and a frequency meter.

On the front panel of the device are:

- knobs «FREQUENCY ROUGHLY» and «FREQUENCY EXACTLY» - for adjustment generator's frequency;

- knob "LEVEL" for adjustment the required amplitude of output generator's voltage (amplitude of string's oscillations);

- liquid-crystal display.

Magnetic force directed perpendicular to the current acts on the string by a current. Because the current is alternating the force changes with the same frequency and swings the string. A generator can change the frequency of the force change. When the frequency of the magnetic force becomes close to the self-resonant frequency of string, resonance occurs and the oscillations increase.

Measurement

1. Connect the device to a 220 V network. Press the "NETWORK" switch of the power supply of the lamp (the lamp is on). Press the "NETWORK" switch of the measuring device (the illumination of the display glows and the frequency is displayed).
2. Give the device time for warming up for 3-5 min.
3. Set the tension of the string 0,4 N. Set the "LEVEL" knob to the middle position.
4. Changing frequency in the range of 20-45 Hz using knobs «FREQUENCY ROUGHLY» and «FREQUENCY EXACTLY» to obtain one well-visible wave on the all string's length.
5. Increasing the frequency, obtain waves at other frequencies. Not less then four.
6. Record the indications of generator and draw the distribution of the oscillation amplitudes of string's points in all cases.
7. Repeat the experiment when string tension is 0.3 N.
8. Calculate self-resonant frequency oscillation for every case and fill up table.

T, N	*n*	*l*, m	ρ, kg/m	*ν* generator, Hz	*ν* calculated, Hz
	1				
	2				
	3				
	1				
	2				
	3				

Control questions

1. What is called a standing wave? Write down the standing wave formula.
2. What is called the node (antinode) of the standing wave?
3. Does the movement of oscillations in space (along the X axis) occur in standing wave?
4. Is there such a state of a standing wave when all the points of the string lie on the straight line? Will the points remain motionless?
5. Does the standing wave transfer energy along the X axis?
6. In what phases do the pointsbetween the two nodes of the string oscillate?
7. Which phases do the pointson both sides of the same node of a string oscillate in?

8. How does the oscillation amplitude change between the two nodes?
9. What is the difference between a standing wave and a running wave?
10. What oscillations of a string are called self-resonant?

Literature

1. І. М. Кучерук та ін. Загальний курс фізики. Т.1. К. 1999.
2. Т.И. Трофимова. Курс физики. М. 2005.