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TECHNOLOGY OF TEACHING GRAPHICS OF FREE MECHANICAL VIBRATION USING "MICROSOFT EXCEL" SOFTWAR

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ANNOTATION
In this article, harmonic oscillations of a mathematical and spring pendulum are considered, and graphs of the dependence of speed and acceleration on time and coordinates were obtained using the Microsoft Excel software tool.
KEY WORDS: ***the equation of motion, velocity, acceleration, amplitude, circular oscillation, the period of oscillation, constant of proportionality, mass, pendulum, spring.***

Annotatsiya: Ushbu maqolada matematik mayatnik va prujinai mayatniklarning garmonik tebranishi hamda tezlik va tezlanishning vaqtga va koordinataga bog'lanish grafiklari "Microsoft Excel" dasturiy vositasi yordamida yoritilgan.

Kalit so'zlar: harakat tenglamasi, tezlik, tezlanishi, amplituda, siklik chastota, tebranish davri, bikrlik, massa, mayatnik, prujina.

Аннотация: В данной статье рассмотрены гармонические колебания математического и пружинного маятника, а также были получены графики зависимости скорости и ускорения от времени и координат, с использованием программного средства "Microsoft Excel".

Ключевые слова: уравнение движения, скорость, ускорение, амплитуда, циклическая частота, период колебаний, жесткость, масса, маятник, пружина.

Informatization of the educational system, the use of modern information technologies and various software tools in the teaching process is one of the urgent issues of today. In particular, in military-academic lyceums and in particular in the "Temurbek maktabi", teaching with the help of computer technologies, showing their graphics using various software tools in the explanation of physical phenomena is an incentive to expand the imagination of the students about the structure of the universe and to form a scientific outlook on objective reality. will be Below we cover the subject of "Harmonic vibrations" which belongs to the "Mechanics" department of physics using the software tool "Microsoft Excel". Usually, in academic lyceums, the topics "Mathematical Pendulum" and "Spring Pendulum" related to the chapter "Mechanical Vibrations and Waves" and the topic of harmonic vibrations are covered extensively. Although the movement of these pendulums is one of the events that happen before our eyes, and all the information about it seems familiar to the readers, there are some aspects that are of special importance. For example, students are familiar with changes of mathematical or spring pendulums only in coordinate axes. However, in this process, not all students are aware of the changes of quantities such as speed and acceleration over time, as well as the laws of connection of these quantities to coordinates. That's why in the article, we will consider in detail all the laws and relationships listed above about information technologies. A mathematical pendulum and also a physical pendulum $x = A\cos\omega t$ or $x = A\sin\omega t$ according to the law of harmonic oscillation, we know very well from the science itself. In this A – vibration amplitude; ω – is the cyclic

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(circular) frequency of vibration, which is for the mathematical pendulum $\omega = \sqrt{\frac{g}{\ell}}$ from the formula, and for the spring pendulum $\omega = \sqrt{\frac{k}{m}}$ is determined using the formula. And the periods of oscillation of these pendulums

$$T = 2\pi\sqrt{\frac{\ell}{g}} \text{ va } T = 2\pi\sqrt{\frac{m}{k}}$$

determined using formulas.

If the movement of a ball on a pendulum or a ball attached to a spring starts from the most extreme position from the equilibrium position, then the oscillation is according to the cosine law, that is $x = A\cos\omega t$ it happens according to the law.

To investigate the time dependence of free harmonic oscillations *x=x(t)* we will need to graph the function. We can do this by taking into account the age and psychology of the students, and in order to avoid the complexity of mastering the simplicity of the program, simply by using the Microsoft Excel spreadsheet, which is familiar to all of us. Let's remind, "Microsoft Excel" spreadsheet ─ there are A, B, C, D, E, ... Columns marked with Latin capital letters such as and 1, 2, 3, 4, ... is an electronic table consisting of lines given by natural numbers such as In this case, each cell comes as an address defined by a column and a row. Each cell contains a number, a word, a logical symbol or a calculation formula.For example, C2 in the cell =2*4+6 if we write, the result of the calculation will be 14.

Now let's get acquainted with how to create a graph of free harmonic oscillations using this "Microsoft Excel" spreadsheet. This opens an electronic window in which the electronic cells initially have constant values for each pendulum. A, g, ℓ and A, m, k let's say letters B2, C2, D2 and F2, G2, H2 let's write in the cells. Under the same cells, that is B3, C3, D3 and F3, G3, H3 the values of these quantities corresponding to the cells, let's say 0,05; 9,8; 1 and 0,05; 1; 100 enter numbers. Then, for each pendulum, the cyclic frequency ω and the oscillation period T B5, C5 and F5, write in cells G5 and calculate their formulas at the bottom B6, C6 and F6, G6 into the cells (1-picture). As the independent variable of the function, we give different positive values equal to the shares of period T to time t in a separate column, this is starting from cells B9 and F9 downwards. And in the adjacent columns C and G, starting from cells C9 and G9 downwards, the function of the arbitrary variable x, let's say $x = A\cos\omega t$ function is introduced. Then the corresponding values of voluntary and non-voluntary variables are obtained in adjacent columns. Having marked these columns, the button "Graphic" is selected from the panel window, and from there the option " Pinpoint" is clicked. Then we get the graphs in Figure 1 below. The diagrams in Figure 1 below show how the mathematical and spring pendulums oscillate over time. Since the pictures are exactly similar, we can generalize our idea and say that the graphs in Picture 1 are the vibrational view of all harmonically vibrating bodies. The greater the number of values in one period, the smoother and clearer the graph will be.

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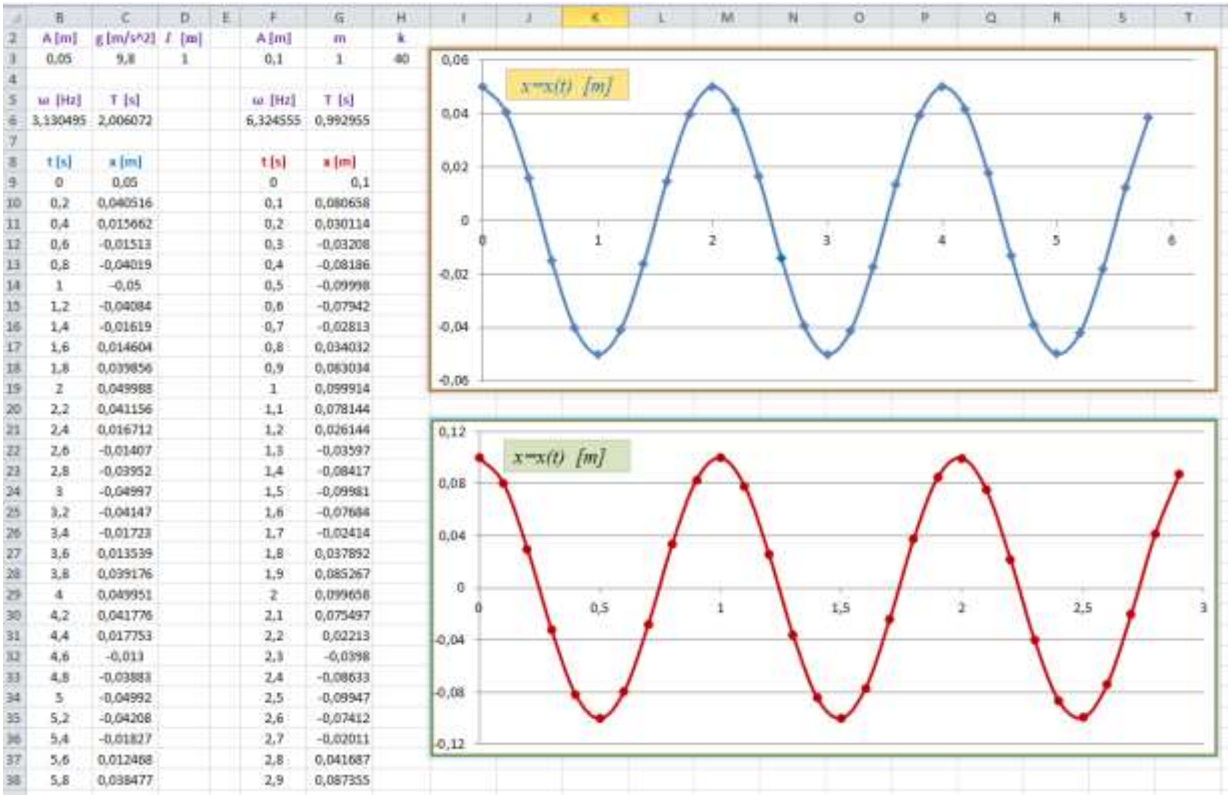

	B	C	D	F	G	H
2	A [m]	g [m/s^2]	ℓ [m]	A [m]	m	k
3	0,05	9,8	1	0,1	1	40
4						
5	ω [Hz]	T [s]		ω [Hz]	T [s]	
6	3,130495	2,006072		6,324555	0,992955	
7						
8	t [s]	x [m]		t [s]	x [m]	
9	0	0,05		0	0,1	
10	0,2	0,040516		0,1	0,080658	
11	0,4	0,015662		0,2	0,030114	
12	0,6	-0,01513		0,3	-0,03208	
13	0,8	-0,04019		0,4	-0,08186	
14	1	-0,05		0,5	-0,09998	
15	1,2	-0,04084		0,6	-0,07942	
16	1,4	-0,01619		0,7	-0,02813	
17	1,6	0,014604		0,8	0,034032	
18	1,8	0,039856		0,9	0,083034	
19	2	0,049988		1	0,099914	
20	2,2	0,041156		1,1	0,078144	
21	2,4	0,016712		1,2	0,026144	
22	2,6	-0,01407		1,3	-0,03597	
23	2,8	-0,03952		1,4	-0,08417	
24	3	-0,04997		1,5	-0,09981	
25	3,2	-0,04147		1,6	-0,07684	
26	3,4	-0,01723		1,7	-0,02414	
27	3,6	0,013539		1,8	0,037892	
28	3,8	0,039176		1,9	0,085267	
29	4	0,049951		2	0,099658	
30	4,2	0,041776		2,1	0,075497	
31	4,4	0,017753		2,2	0,02213	
32	4,6	-0,013		2,3	-0,0398	
33	4,8	-0,03883		2,4	-0,08633	
34	5	-0,04992		2,5	-0,09947	
35	5,2	-0,04208		2,6	-0,07412	
36	5,4	-0,01827		2,7	-0,02011	
37	5,6	0,012468		2,8	0,041687	
38	5,8	0,038477		2,9	0,087355	

Figure-1

Now let's see how the graphs of speed and acceleration versus time look like.

If the movement of a ball on a pendulum or a ball attached to a spring starts from the most extreme position from the equilibrium position, then the oscillation is according to the cosine law, this is $x = A\cos\omega t$ it happens according to the law. In this case the velocity functions

$$\vartheta = -A\omega\sin\omega t = -A\sqrt{\frac{g}{\ell}}\sin\left(\sqrt{\frac{g}{\ell}}\,t\right) \quad \text{and} \quad \vartheta = -A\omega\sin\omega t = -A\sqrt{\frac{k}{m}}\sin\left(\sqrt{\frac{k}{m}}\,t\right)$$

and acceleration functions $a = -A\omega^2\cos\omega t = -\frac{gA}{\ell}\cos\left(\sqrt{\frac{g}{\ell}}\,t\right)$ and $a = -A\omega^2\cos\omega t = -A\frac{k}{m}\cos\left(\sqrt{\frac{k}{m}}\,t\right)$

it will look like. We can generate graphs of these using the Microsoft Excel spreadsheet, just like the equation of motion.

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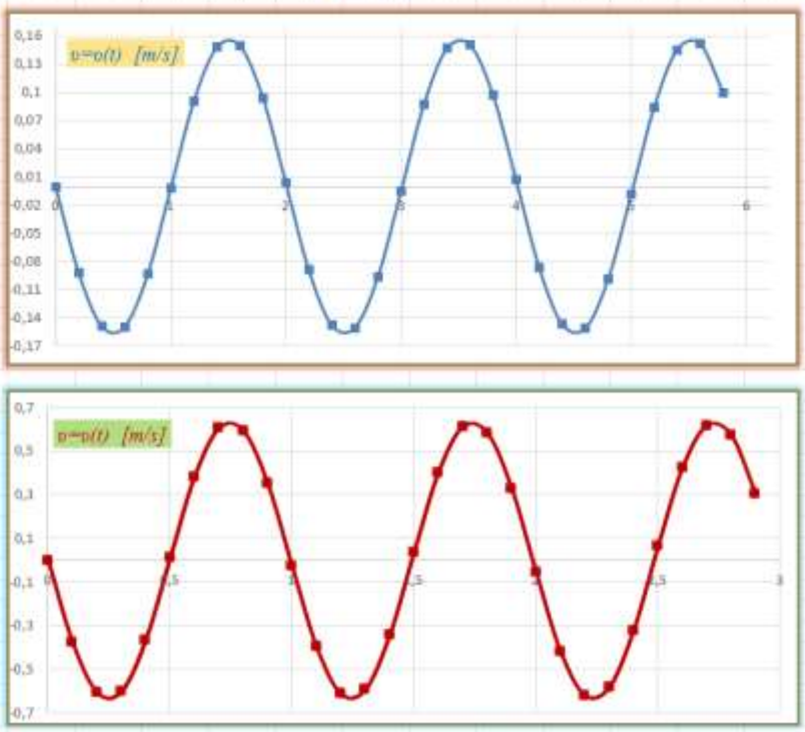
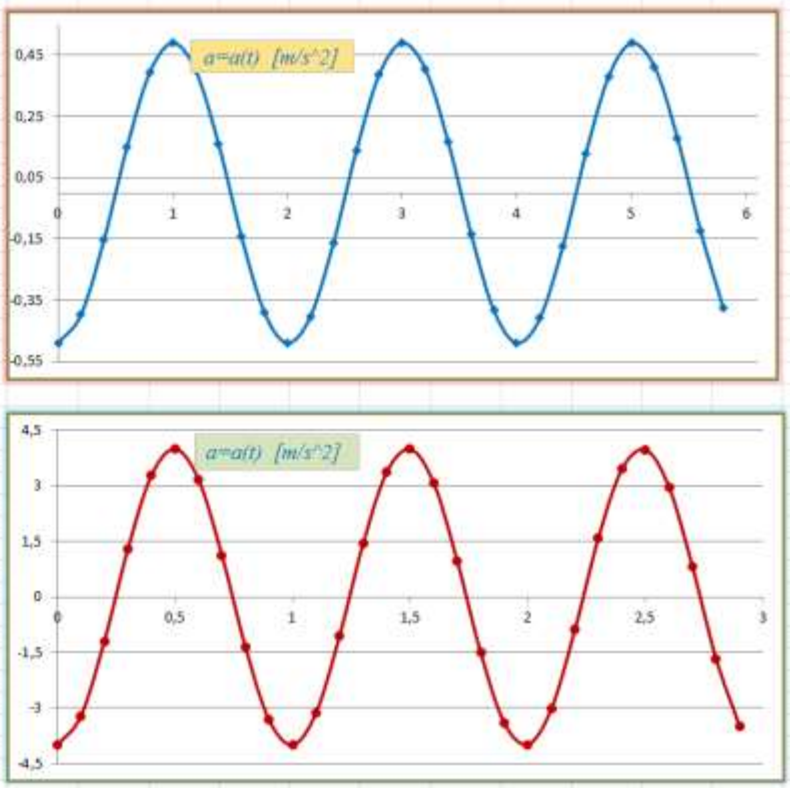


	B	C	D	F	G	H
2	A [m]	g [m/s^2]	*l* [m]	A [m]	m	k
3	0,05	9,8	1	0,1	1	40
4						
5	ω [Hz]	T [s]		ω [Hz]	T [s]	
6	3,130495	2,006072		6,32456	0,992955	
7						
8	t [s]	υ [m/s]		t [s]	υ [m/s]	
9	0	0		0	0	
10	0,2	-0,09172		0,1	-0,37386	
11	0,4	-0,14865		0,2	-0,6031	
12	0,6	-0,14918		0,3	-0,59903	
13	0,8	-0,09312		0,4	-0,36323	
14	1	-0,00174		0,5	0,013081	
15	1,2	0,090308		0,6	0,384333	
16	1,4	0,148094		0,7	0,606908	
17	1,6	0,149699		0,8	0,594704	
18	1,8	0,094514		0,9	0,352444	
19	2	0,003474		1	-0,02616	
20	2,2	-0,08888		1,1	-0,39464	
21	2,4	-0,14752		1,2	-0,61046	
22	2,6	-0,1502		1,3	-0,59013	
23	2,8	-0,09589		1,4	-0,34151	
24	3	-0,00521		1,5	0,039222	
25	3,2	0,087449		1,6	0,404778	
26	3,4	0,146933		1,7	0,613748	
27	3,6	0,150677		1,8	0,585294	
28	3,8	0,09726		1,9	0,330423	
29	4	0,006946		2	-0,05227	
30	4,2	-0,086		2,1	-0,41474	
31	4,4	-0,14633		2,2	-0,61877	
32	4,6	-0,15114		2,3	-0,58021	
33	4,8	-0,09861		2,4	-0,3192	
34	5	-0,00868		2,5	0,065295	
35	5,2	0,084546		2,6	0,42453	
36	5,4	0,1457		2,7	0,619538	
37	5,6	0,151581		2,8	0,574882	
38	5,8	0,099957		2,9	0,307837	

Then we have the graphs in Figure 2 for the velocity equation and in Figure 3 for the acceleration equation.

Figure-2



	B	C	D	F	G	H
2	A [m]	g [m/s^2]	*l* [m]	A [m]	m	k
3	0,05	9,8	1	0,1	1	40
4						
5	ω [Hz]	T [s]		ω [Hz]	T [s]	
6	3,130495	2,006072		6,32456	0,992955	
7						
8	t [s]	a [m/s^2]		t [s]	a [m/s^2]	
9	0	-0,49		0	-4	
10	0,2	-0,39706		0,1	-3,22631	
11	0,4	-0,15349		0,2	-1,20455	
12	0,6	0,148312		0,3	1,283186	
13	0,8	0,393846		0,4	3,27453	
14	1	0,48997		0,5	3,999144	
15	1,2	0,400219		0,6	3,176717	
16	1,4	0,15864		0,7	1,125398	
17	1,6	-0,14312		0,8	-1,36127	
18	1,8	-0,39059		0,9	-3,32134	
19	2	-0,48988		1	-3,99658	
20	2,2	-0,40333		1,1	-3,12576	
21	2,4	-0,16378		1,2	-1,04577	
22	2,6	0,137911		1,3	1,438777	
23	2,8	0,387279		1,4	3,366739	
24	3	0,489728		1,5	3,992301	
25	3,2	0,406394		1,6	3,073468	
26	3,4	0,16889		1,7	0,965685	
27	3,6	-0,13268		1,8	-1,51567	
28	3,8	-0,38392		1,9	-3,41069	
29	4	-0,48952		2	-3,98632	
30	4,2	-0,40941		2,1	-3,01986	
31	4,4	-0,17398		2,2	-0,88519	
32	4,6	0,127442		2,3	1,591907	
33	4,8	0,380521		2,4	3,453187	
34	5	0,489246		2,5	3,978626	
35	5,2	0,41237		2,6	2,96496	
36	5,4	0,179057		2,7	0,80432	
37	5,6	-0,12218		2,8	-1,66747	
38	5,8	-0,37707		2,9	-3,4942	

Figure-3

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From the figure 1 above and the figures 2 and 3 below, which we have seen, it can be seen that coordinate, velocity and acceleration fluctuations do not occur in exactly one phase. The difference between the oscillation phases of coordinate and velocity and velocity and acceleration is equal to p/2. And the distance between the phases of coordinate and acceleration oscillations differs by p, that is, they oscillate in the opposite phase. In addition, it is necessary to pay special attention to the fact that, regardless of whether it is a mathematical pendulum or a spring pendulum, the equations of motion, speed and acceleration of all harmonically vibrating bodies are similar. Now let's look at how the graphs of the magnitudes of speed and acceleration look like.

To do this, we need to convert the connection of speed and acceleration to time into the form of connection to the coordinate. In this case, we use the trigonometric equation familiar to us from "Trigonometry".

$$\sin^2\alpha+\cos^2\alpha=1, \quad \Rightarrow \quad \begin{cases}\sin\alpha=\pm\sqrt{1-\cos^2\alpha}\\ \cos\alpha=\pm\sqrt{1-\sin^2\alpha}\end{cases}$$

In addition, the equation of motion of the pendulum $x=A\cos\omega t$ from $\cos\omega t=\dfrac{x}{A}$ we create and use it as well.

$$\vartheta=-A\omega\sin\omega t=-A\omega\left(\pm\sqrt{1-\cos^2\omega t}\right)=\mp A\omega\sqrt{1-\left(\frac{x}{A}\right)^2}=\mp\omega\sqrt{A^2-x^2}$$

$$a=-A\omega^2\cos\omega t=-A\omega^2\frac{x}{A}=-\omega^2 x$$

Thus, the connection of the speed of the mathematical pendulum and the spring pendulum to the coordinate

$$\vartheta=\mp\omega\sqrt{A^2-x^2}=\mp\sqrt{\frac{g}{\ell}\left(A^2-x^2\right)} \text{ va } \vartheta=\mp\omega\sqrt{A^2-x^2}=\mp\sqrt{\frac{k}{m}\left(A^2-x^2\right)}$$

on the basis of regularity and connection of acceleration to the coordinate $a=-\omega^2 x=-\dfrac{g}{\ell}x$ and $a=-\omega^2 x=-\dfrac{k}{m}x$ as it changes based on the law. In the velocity equation $\mp$ In the first half of the signs, the (-) sign is selected, and in the second half, the (+) sign is selected.

The connection of velocity and acceleration to the coordinate given above, this is $\vartheta=\vartheta(x)$ va $a=a(x)$ if we make the graphs of the equations using the values given above for myatniks, we will have pictures 4 and 5. In this x coordinate value $-A\le x\le A$ we have it.

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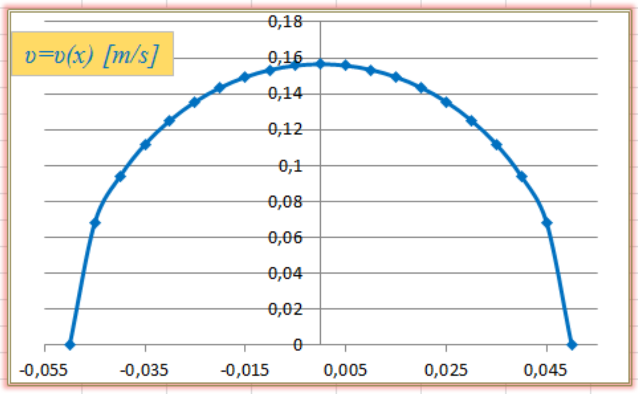
	B	C	D	E	F	G	H
1							
2	A [m]	g [m/s^2]	l [m]		A [m]	m	k
3	0,05	9,8	1		0,1	1	40
4							
5	ω [Hz]	T [s]			ω [Hz]	T [s]	
6	3,130495	2,006072			6,324555	0,992955	
7							
8	x [m]	υ [m/s]			x [m]	υ [m/s]	
9	-0,05	0			-0,1	0	
10	-0,045	0,068228			-0,09	0,275681	
11	-0,04	0,093915			-0,08	0,379473	
12	-0,035	0,111781			-0,07	0,451664	
13	-0,03	0,12522			-0,06	0,505964	
14	-0,025	0,135554			-0,05	0,547723	
15	-0,02	0,143457			-0,04	0,579655	
16	-0,015	0,149315			-0,03	0,603324	
17	-0,01	0,153362			-0,02	0,619677	
18	-0,005	0,15574			-0,01	0,629285	
19	0	0,156525			0	0,632456	
20	0,005	0,15574			0,01	0,629285	
21	0,01	0,153362			0,02	0,619677	
22	0,015	0,149315			0,03	0,603324	
23	0,02	0,143457			0,04	0,579655	
24	0,025	0,135554			0,05	0,547723	
25	0,03	0,12522			0,06	0,505964	
26	0,035	0,111781			0,07	0,451664	
27	0,04	0,093915			0,08	0,379473	
28	0,045	0,068228			0,09	0,275681	
29	0,05	0			0,1	0	
30							
31							



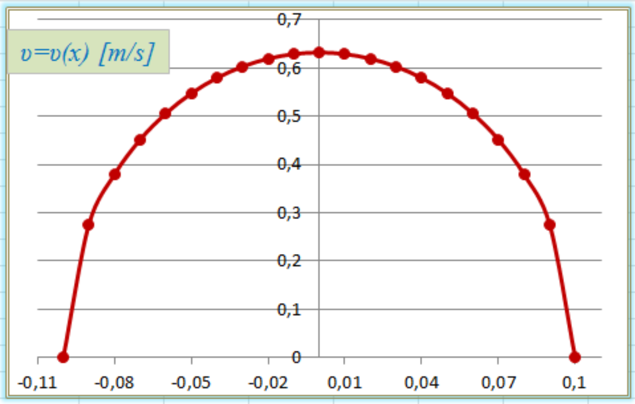


Figure-4

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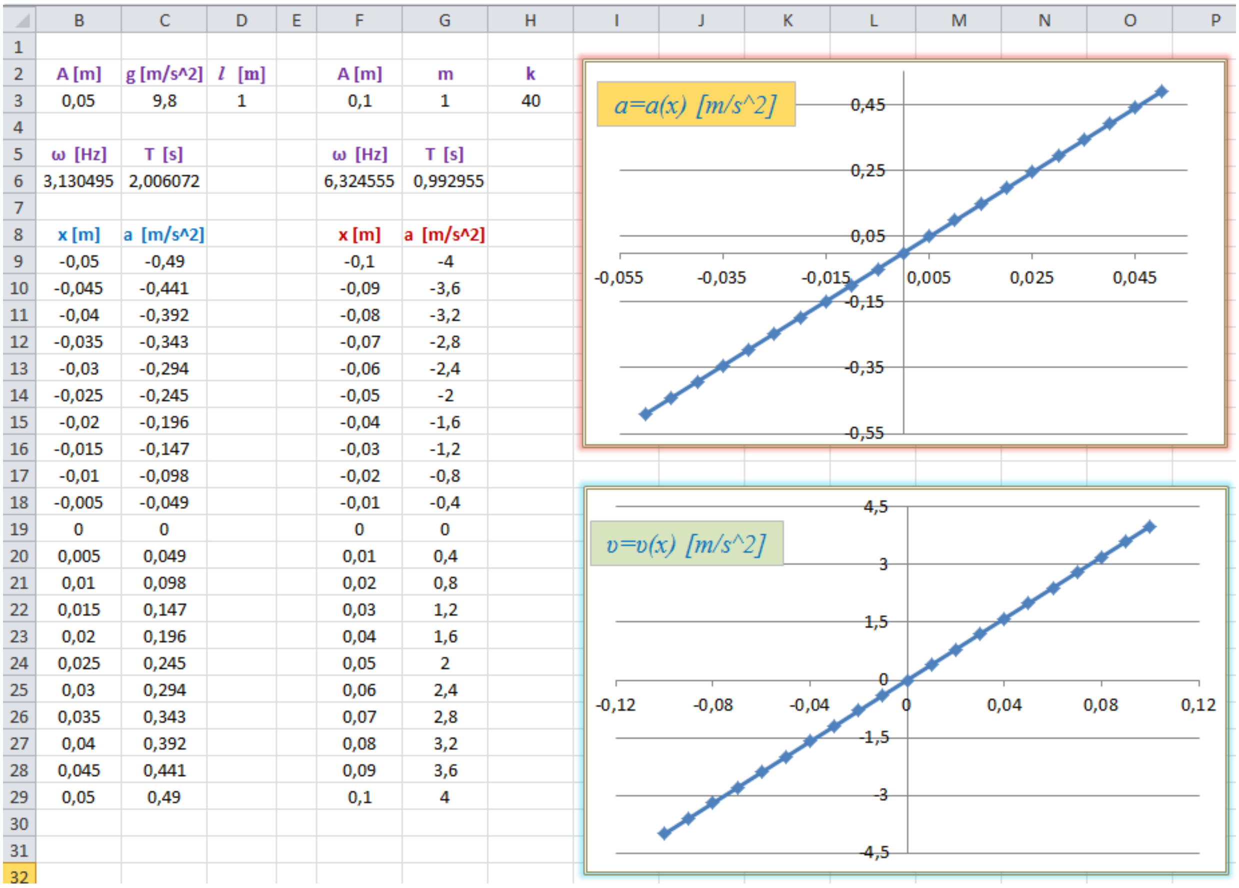

	B	C	D	F	G	H
2	A [m]	g [m/s^2]	l [m]	A [m]	m	k
3	0,05	9,8	1	0,1	1	40
5	ω [Hz]	T [s]		ω [Hz]	T [s]	
6	3,130495	2,006072		6,324555	0,992955	
8	x [m]	a [m/s^2]		x [m]	a [m/s^2]	
9	-0,05	-0,49		-0,1	-4	
10	-0,045	-0,441		-0,09	-3,6	
11	-0,04	-0,392		-0,08	-3,2	
12	-0,035	-0,343		-0,07	-2,8	
13	-0,03	-0,294		-0,06	-2,4	
14	-0,025	-0,245		-0,05	-2	
15	-0,02	-0,196		-0,04	-1,6	
16	-0,015	-0,147		-0,03	-1,2	
17	-0,01	-0,098		-0,02	-0,8	
18	-0,005	-0,049		-0,01	-0,4	
19	0	0		0	0	
20	0,005	0,049		0,01	0,4	
21	0,01	0,098		0,02	0,8	
22	0,015	0,147		0,03	1,2	
23	0,02	0,196		0,04	1,6	
24	0,025	0,245		0,05	2	
25	0,03	0,294		0,06	2,4	
26	0,035	0,343		0,07	2,8	
27	0,04	0,392		0,08	3,2	
28	0,045	0,441		0,09	3,6	
29	0,05	0,49		0,1	4	

Figure-5

Figures 4 and 5 show that any pendulum (mathematical or spring or other type) with free harmonic oscillation for $\vartheta=\vartheta(x)$ the graph of the function is in the form of a circular arc, $a=a(x)$ and the graph of the function is in a linear view.

Thus, we learned how to create graphs of the movement, speed and acceleration of harmonically vibrating bodies using the Microsoft Excel software tool, and we learned that the shape of the graphs does not depend on the type of pendulum. In general, there are many and various software tools that can be used to create these graphs and calculate various quantities in these oscillatory processes. However, from the point of view of the fact that it is easier for students of academic lyceums to understand and master, we chose the software tool "Microsoft Excel".

Advantages of teaching the subject using various modern software tools:

– serves to expand students' thinking and imagination about vibrational processes;
– trains students to use information technologies;
– simplifies calculations and saves time;
– achieved a clear result.

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